National Aeronautics and
Space Administration

JSC 14651

Lyndon B. Johnson Space Center
Houston Texas 77058

ORBITER SUBSYSTEM

HARDWARE/SOFTWARE INTERACTION ANALYSIS

VOLUME VIII: FORWARD REACTION CONTROL SYSTEM

January 1980

PREFACE

The Orbiter subsystem hardware/software interaction analysis examines software interaction with hardware failure modes. Each failure mode identified in subsystem FMEA (failure mode and effects analysis) is examined for interaction with software. The analysis is based upon key questions which identify potential issues. These potential issues are to be resolved by providing rationale for retention or identifying and implementing changes to eliminate the issue.

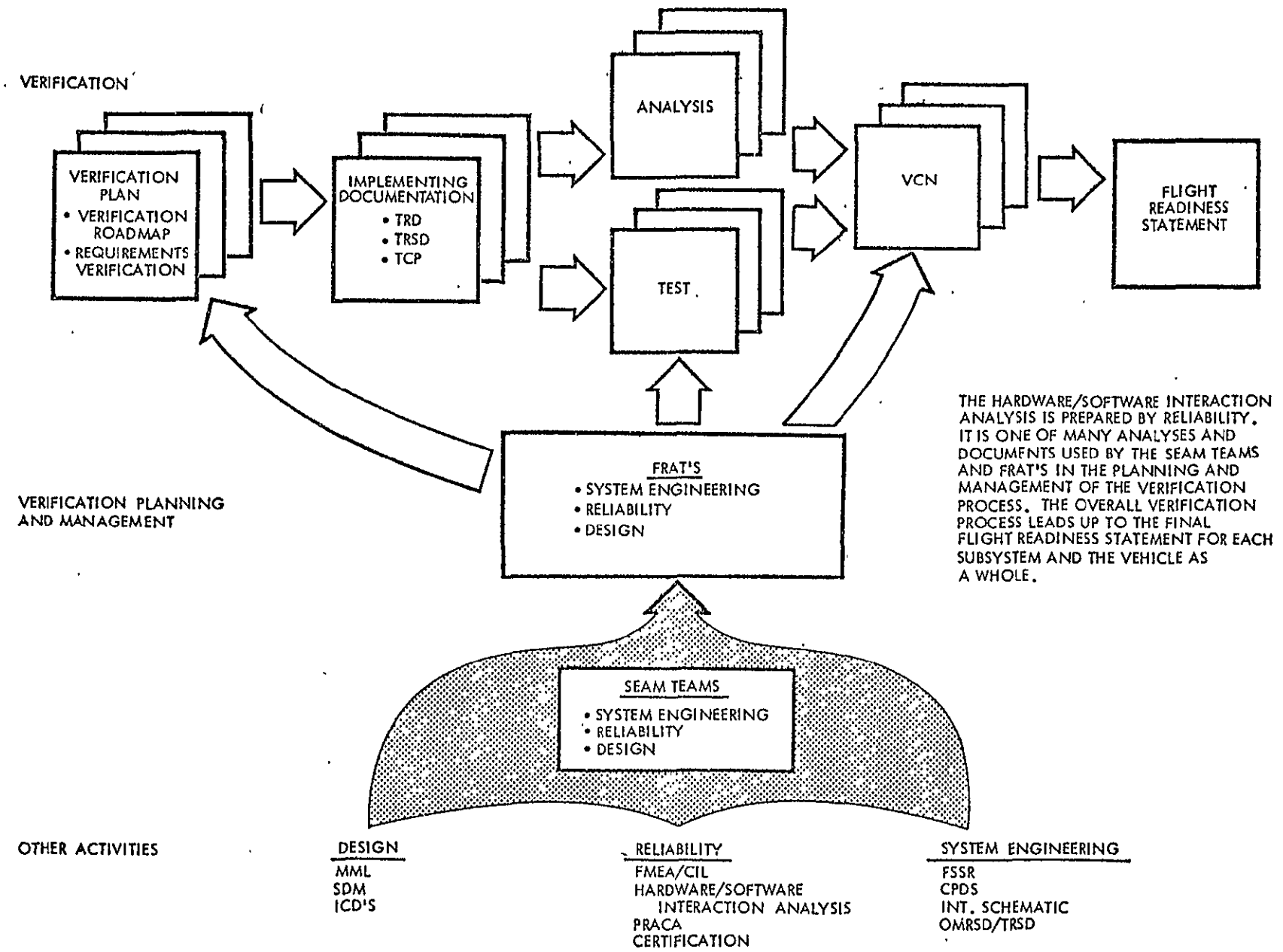
The figure on the following page illustrates the relationship of the hardware/software interaction analysis to the verification process which leads to the statement of flight readiness. As shown, the analysis is a supporting item which is a portion of the data base utilized by the FRAT's (flight readiness assessment teams) and the associated SEAM (Systems Engineering Assessment Meeting) teams in planning and controlling the verification process. The overall issue of hardware/software interface compatibility is addressed by the verification process itself. The analysis scope is limited to examination of single failure modes, as identified in the FMEA, and the interaction of these failure modes with the software as reflected by the software requirements.

The hardware/software interaction analysis is performed on a preliminary basis by the JSC Reliability Division. Results are then coordinated with JSC engineering and Rockwell/Space Systems Group engineering and reliability to obtain inputs and approval signatures. The approval sheet for the Forward Reaction Control System are presented below. The Rockwell signatures represent their review of the open issues and risks, if any, performed against the summarization of the analysis. Section 5.0 presents the analysis summary which groups the failure modes by similar retention rationale and is a convenience in identifying groups of failure modes in which the analysis is similar. The reviews with Rockwell did not cover each checklist. The minutes presented in the appendix document the nature and depth of the Rockwell analysis review.

This analysis verified that no open issues remain.

Approved: Joseph H. Levine 11/4/80

Joseph H. Levine
Chief, Reliability Division


VERIFICATION
VERIFICATION PLAN
• VERIFICATION ROADMAP
• REQUIREMENTS VERIFICATION
IMPLEMENTING DOCUMENTATION
• TRD
• TRSD
• TCP
ANALYSIS
TEST
VCN
FLIGHT READINESS STATEMENT
FRAT'S
• SYSTEM ENGINEERING
• RELIABILITY
• DESIGN
VERIFICATION PLANNING AND MANAGEMENT
THE HARDWARE/SOFTWARE INTERACTION ANALYSIS IS PREPARED BY RELIABILITY. IT IS ONE OF MANY ANALYSES AND DOCUMENTS USED BY THE SEAM TEAMS AND FRAT'S IN THE PLANNING AND MANAGEMENT OF THE VERIFICATION PROCESS. THE OVERALL VERIFICATION PROCESS LEADS UP TO THE FINAL FLIGHT READINESS STATEMENT FOR EACH SUBSYSTEM AND THE VEHICLE AS A WHOLE.
SEAM TEAMS
• SYSTEM ENGINEERING
• RELIABILITY
• DESIGN
OTHER ACTIVITIES
DESIGN
MML
SDM
ICD'S
RELIABILITY
FMEA/CIL
HARDWARE/SOFTWARE INTERACTION ANALYSIS
PRACA
CERTIFICATION
SYSTEM ENGINEERING
FSSR
CPDS
INT. SCHEMATIC
OMRSD/TRSD

HARDWARE/SOFTWARE INTERACTION ANALYSIS

Forward Reaction Control System
SUBSYSTEM

FMEA # SD75-SH-0016A

ANALYSIS DATE June 25, 1979

For D R Eagle
HARDWARE/SOFTWARE ANALYST

APPROVED:

Kara Smith
JSC Reliability

J W Jackson
JSC Engineering - FRAT Sponsor

V C Estrada 1/4/80
Rockwell Reliability

Wm F Meyers
Rockwell Engineering - FRAT Sponsor

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1.0 INTRODUCTION. This report documents the results of the analysis of the hardware/software interaction analysis for the Forward Reaction Control System. This analysis examines the interaction between hardware failure modes and software in order to identify associated issues/risks. These issues/risks are resolved through changes to software requirements to remove them, or surfaced to project/program management with appropriate retention rationale.

2.0 SCOPE. All Orbiter subsystems and interfacing program elements which interact with the Orbiter computer flight software are analyzed. The analysis for each subsystem or interfacing element is presented in a separate volume of this report (see section 3.1).

The analysis examines failure modes identified in the subsystem/element FMEA (failure mode and effects analysis). Potential interaction with software is examined through evaluation of the software requirements, not detailed implementation. The analysis is restricted to flight software requirements only, and excludes utility/checkout software. The BFS (backup flight system) software is considered only as necessary, and only as it differs from the primary; the basic thrust of the analysis is keyed to the primary system.

The analysis is based upon the hardware design and software requirements as they existed as of the date of the analysis. Future updates will be published as necessary to incorporate changes to either the hardware or software.

3.0 APPLICABLE DOCUMENTS.

3.1 HARDWARE/SOFTWARE INTERACTION ANALYSIS REPORT VOLUMES. The hardware/software interaction analysis results are reported on a subsystem basis, each in a separate volume. The separate volumes which make up this report are as follows:

Volume	Subsystem
I	Purge, Vent, and Drain
II	Payload Deployment and Retention
III	Payload Bay Doors
IV	Main Propulsion
V	Data Processing Subsystem
VI	Hydraulics
VII	Auxiliary Power Unit
VIII	Reaction Control
IX	Electrical Power
X	Orbital Maneuvering
XI	Environmental Control and Life Support
XII	Integrated Avionics
XIII	Electrical Power Distribution & Control
XIV	GNC (Guidance, Navigation & Control) Support
XV	Displays & Controls
XVI	Communications & Tracking
XVII	Instrumentation

3.2 REFERENCE DOCUMENTS. The primary documents used in performing the analysis included the following:

a. SD75-SH-0016A, "Failure Mode Effects Analysis, Forward Reaction Control Subsystem," Dec 18, 1978.

b. JSC 11174, "OV-102 Space Shuttle Systems Handbook," September 22, 1977.

c. SD76-SH-0026A, "Functional Subsystem Software Requirements, Sequence Requirements," March, 1978.

d. SD76-SH-0020, "Functional Subsystem Software Requirements, Displays and Controls," February 1, 1978.

e. SD76-SH-0027D, "Functional Subsystem Software Requirements, Systems Management," October 16, 1978.

f. MG038103, "Backup Flight System Management/Special Processes and Sequencing Program Requirements Document," December 20, 1978.

g. SD75-SH-0010E, "Functional Subsystem Software Requirements, Redundancy Management," June 1, 1979.

4.0 DESCRIPTION.

4.1 GROUND RULES. The hardware software analysis is performed according to the following ground rules:

a. The hardware/software analysis will be limited to investigating the software interaction with the failure modes of the hardware as delineated in the subsystem FMEA's.

b. Software interaction will be limited to involvement of software of the onboard computers.

c. Only failure modes of hardware with software interfaces (software monitoring and/or software control) are analyzed.

d. The software detection must be considered with respect to each phase of the mission [prelaunch (OPS 1 only), ascent, onorbit, and entry].

4.2 ANALYSIS CHECKLIST. The basic tool for the analysis is the checklist (figure 4-1). A separate checklist is used for each failure mode analyzed. Note that the "FMEA Number" in the heading refers to the FMEA document number, not the page number on which the failure mode is treated.

The checklist consists of three sections: Body, change/retention rationale summary, and explanation/comments. Each of these sections is dicussed below.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST

SUBSYSTEM _____ FMEA NUMBER _____

ITEM _____ FAILURE MODE _____

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES ☐ NO ☐
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES ☐ NO ☐
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES ☐ *NO ☐
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES ☐ NO ☐
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES ☐ NO ☐
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES ☐ NO ☐
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES ☐ NO ☐
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 ☐ *1 ☐ 2 ☐
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A ☐ YES ☐ NO ☐
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES ☐ *NO ☐
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES ☐ *NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☐ NO H/S ISSUES
2. ☐ HARDWARE ACCEPTS RISK
3. ☐ NO SOFTWARE DETECTION
4. ☐ DETECTION DURING CHECKOUT
5. ☐ ACCEPTANCE RATIONALE BELOW
6. ☐ RECOMMENDED CHANGES BELOW

☐ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

Figure 4-1. Hardware/Software Analysis Checklist.

The questions in the checklist body are answered using the following guidelines:

a. Question 1. Will the information provided to the onboard software and the processing of that information cause annunciation of the failure and/or initiation of a corrective action in response to this failure mode?

b. Question 1a. Answer question 1a. if the answer to question 1 is "no." Information available to the software could be in the form of (1) sensor data used by onboard software but not for automatic fault detection (data used in software routines or fault detection available through callup or dedicated displays); (2) system and/or subsystem performance parameters; or (3) measurements which are downlisted. Answer "yes" if such information could be used to annunciate the failure condition or initiate responsive action. In explanation comments, specifically identify the information available for software detection.

c. Question 2. If all of the following questions are answered "no," check the "no" block and explain the difference in the explanation/comments section:

(1) Are the master measurements listed under "Failure Detectability In-flight" on the FMEA (1) used by the onboard software in detecting time critical failures (if routed to GPC), or (2) used by the onboard software in annunciating non-time critical failures via callup displays, or (3) downlisted for non-time critical failures?

(2) Are other measurements, dedicated displays, crew detection, and system/subsystem parameters available or able to detect this failure mode?

(3) If "failure detectability in-flight" specifies only software action, does the software actually initiate the corrective action as called out in the "corrective action" portion of the FMEA?

d. Question 3. The question considers only the cases wherein the software determines a failure.

e. Question 3a. Answer question 3a if the answer to 3 is "no." If the answer to 3a is "yes," call out the possible corrective action in the explanation/comments section.

f. Question 4. The question is considered for both the detected and the undetected failure. The overstress or inducement of another failure may be acceptable action. Overstress by software is improper commands, sequencing, or timing resulting in action exceeding hardware design requirements or exposing hardware to excessive environments.

g. Question 5. The question is considered for both the detected and the undetected failure. Limit adverse effects to effects directly resulting from software commands or subsequent actions resulting from erroneous inputs as a result of the failure.

h. Question 6. The hardware/software may change the method of detection and/or correction after the first or the second failure; consider this in answering the question. Determine if the software will be able to use the redundance of the hardware. If the hardware/software interaction following the particular failure mode changes the criticality, in comparison to the FMEA, check the box provided in the summary section of the checklist.

i. Question 7. If crew action is not required to respond to the failure, check the "N/A" block. Cues which provide inputs to the crew include but are not limited to cathode-ray tube annunciation, caution and warning, visual cues, audible cues, callup and dedicated displays, subsystem status data, panel meters, etc.

j. Question 8.A and 8.B. Answer these questions only if either question 1 or 3 is "yes."

(1) Question 8.A. Consider that the failure occurs while the vehicle is being flown using the primary system. What will happen if the BFS must be engaged subsequent to the failure? Will the fact that the failure has occurred prevent the BFS from operating properly, under any conditions? A "no" answer is a potential issue (requiring explanation) only if the BFS can normally tolerate the failure (when it occurs during BFS operation).

(2) Question 8.B. Consider that the failure occurs while the vehicle is under BFS control. A "no" answer is an issue (requiring explanation) only if the BFS response differs from that for the primary system.

4.2.2 Change/Retention Rationale Summary. Each failure is assigned to one of six possible groups, based upon the answers obtained in the checklist body. Boxes are provided to indicate the category assigned. Figure 4-2 presents the criteria for group assignment.

A box is also provided to indicate that changes are required to the FMEA. The FMEA evaluation of in-flight detectability is sometimes inaccurate and requires change. In addition, other errors (e.g., incorrect criticality assignment or incorrect evaluation of redundancy screens) are occasionally noted during the analysis and are documented here.

A space is provided to detail acceptance rationale, change recommendations, or suggested FMEA changes. This space may also be used to provide a short general comment to expand the retention rationale grouping.

4.2.3 Explanation/Comments. Each question answered by checking a box identified with an asterisk is discussed in this section. The circumstances for checking a box not identified with an asterisk are discussed, and the rationale for not making such a change is presented, if applicable. This section may also be used to explain, expand, or qualify answers. Each discussion is identified with the corresponding question number.

4.3 ANALYSIS SUMMARY. The analysis results are summarized on the basis of retention rationale grouping and recommended changes/retention rationale. Figure 4-3 depicts the form utilized for this purpose. A particular retention rationale definition, acceptance rationale statement, or recommended change is listed in the left column, with the applicable failure modes listed on the right. The issue/risk is briefly described with acceptance rationale or software requirements change recommendation. The summary provides a basic overview of the total analysis results.

5.0 ANALYSIS SUMMARY SHEETS. The analysis results are summarized on the following sheets. The failure modes have been grouped by issue/retention rationale (or change), affording an overview of the results for the entire subsystem.

CHANGE/RETENTION RATIONALE

1. NO * CHECKED - NO HARDWARE/SOFTWARE ISSUES ARE APPARENT FROM THE ANALYSIS. SYSTEM IS FAIL OPERATIONAL/FAIL SAFE WITH RESPECT TO THIS FAILURE MODE UNDER CURRENT DESIGN.

2. ONLY * CHECKED ON QUESTION 6 - NO HARDWARE/SOFTWARE ISSUES ARE APPARENT FROM THE ANALYSIS. RISK HAS BEEN ACCEPTED VIA HARDWARE CIL.

3. ONLY * (YES) CHECKED ON QUESTION 1a - NO SOFTWARE DETECTION IS PROVIDED. FAILURE EFFECT IS NOT TIME CRITICAL. FAILURE MAY BE DETECTED BY OTHER MEANS OR FUNCTION IS NOT MISSION/SAFETY CRITICAL.

4. * CHECKED ON QUESTION 3a - * ON 1a MAY OR MAY NOT BE CHECKED - SOFTWARE DOES NOT TAKE CORRECTIVE ACTION FOR FAILURE. FAILURE EFFECT IS NOT TIME CRITICAL. CORRECTIVE ACTION MAY BE INITIATED BY CREW. PLANNED CHECKOUT ACTIVITIES WILL DETECT FAILURE. SYSTEM IS FAIL OPERATIONAL/FAIL SAFE WITHOUT SOFTWARE DETECTION AND CORRECTION.

5. STANDARD RETENTION RATIONALE DOES NOT APPLY. SPECIFIC RETENTION RATIONALE IS SUMMARIZED FOR THIS FAILURE.

6. ISSUES IDENTIFIED AND CHANGES ARE DESIRABLE. SPECIFIC CHANGES ARE SUMMARIZED.

NOTE: DO NOT CONSIDER ANSWER TO QUESTION 2 IN DETERMINATION OF CHANGE/RETENTION RATIONALE SUMMARY CODE. CONSIDER RESPONSES TO BOTH QUESTION 2 AND 6 IN DETERMINING WHETHER AN FMEA CHANGE IS REQUIRED.

Figure 4-2. Change/Retention Rationale

HARDWARE/SOFTWARE ANALYSIS SUMMARY

SUBSYSTEM ______________________ FMEA ____________________

ANALYSIS RESULT	ITEM/FAILURE MODE

Figure 4-3. Hardware/Software Analysis Summary

HARDWARE/SOFTWARE ANALYSIS SUMMARY

SUBSYSTEM Forward Reaction Control

FMEA SD75-SH-0016A

ANALYSIS RESULT	ITEM/FAILURE MODE
HARDWARE ACCEPTS RISK	Helium Storage Tank - Rupture (03-2F-101010-1) Helium Feedline - External Leakage (03-2F-101013-1) Quick Fill Disconnect, He - Fails Open, Cap Leaks (03-2F-101070-1) Test Quick Disconnect, Propellant - Ext. Leakage/Flight (03-2F-101090-1) Propellant Line Flex Assy. - External Leakage (03-2F-102106-1) Feedline and Fittings - External Leakage (03-2F-102108-1) AC Motor Operated Valve (Tank) - Fails Closed (03-2F-102120-1) Quick Disconnect - External Leakage (03-2F-102150-1) DC Solenoid Operated Valve - Fails Closed - Premature Operation (03-2F-102170-1) Tank Assembly and Propellant Acquisition Device - Small Crack - External Leakage (03-2F-111110-2) Tank Assembly and Propellant Acquisition Device - Restricted Flow (03-2F-111110-3) Tank Assembly and Propellant Acquisition Device - Loss of Gas in Propellant Acquisition Device (03-2F-111110-4) Flex Line and Fittings - External Leakage (03-2F-121308-1) Thrust Chamber - Burn Through (03-2F-121312-1) Nozzle Extension - Burn-Through (03-2F-121313-1) Vernier Thruster - Erratic Operation (03-2F-131310-3) Vernier Thruster - Burn-Through (03-2F-131310-4) Helium Pressure Regulator - Fails Closed (03-2F-101030-2) Tank Assembly and Propellant Acquisition Device - Large Rupture (03-2F-111110-1) Purge Quick Disconnect, Propellant - External Leakage During Flight (03-2F-101080-1) Helium Quad Check Valve - Fails Closed (03-2F-101095-2) Vernier Thruster - Loss of Output (03-2F-131310-1)

HARDWARE/SOFTWARE ANALYSIS SUMMARY

SUBSYSTEM Forward Reaction Control

FMEA SD75-SH-0016A

ANALYSIS RESULT	ITEM/FAILURE MODE
NO HARDWARE/SOFTWARE ISSUES	D.C. Solenoid Valve - Fails to Close (03-2F-101020-3) D.C. Solenoid Valve - Fails Closed (03-2F-101020-4) Helium Pressure Regulator - Fails Open (03-2F-101030-1) Relief Valve - External Leakage Overboard (03-2F-101060-1) Relief Valve - Burst Disc Ruptures (03-2F-101060-2) Relief Valve - Fails to Burst (03-2F-101060-3) Relief Valve - Opens Low (03-2F-101060-4) Relief Valve - Fails to Open (03-2F-101060-5) Helium Quad Check Valve - Fails Open (03-2F-101095-1) Injector Plate - Mixture (03-2F-121311-1)

SUBSYSTEM Forward Reaction Control

FMEA SD75-SH-0016A

ANALYSIS RESULT	ITEM/FAILURE MODE
OUT OF SCOPE - GROUND ONLY	Manual Valve - Fails Closed or Open (03-2F-101050-1)
	Manual Valve - Internal Leakage (03-2F-101050-2)
	Quick Fill Disconnect, He. - Fails Closed/Ground OPS (03-2F-101070-2)
	Purge Quick Disconnect, Propellant - Fails Closed/Ground OPS. (03-2F-101080-2)
	Test Quick Disconnect, Propellant - Fails Closed/Ground Ops (03-2F-101090-2)
	Quick Disconnect - Fails Closed/Ground Ops. (03-2F-102150-2)

6.0 ANALYSIS CHECKLIST SHEETS

Following are the analysis checklist sheets for each failure mode evaluated.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101010-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Helium Storage Tank FAILURE MODE Rupture

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X]	*1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [ ]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [ ]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. GAX will give a class 2 alert upon sensing an out-of-tolerance condition. (≤500 psi) Gross leak detection will give a class 2 alert.

8. Backup flight system same as primary.

```
 SUBSYSTEM :FWD - REACTION CONTROL     FMEA NO 03-2F -10101C-1     REV:12/18/7
.ASSEMBLY  :PRESSURIZATION             ABORT:                 CRIT. FUNC:   1
.P/N RI    :MC282-0082-0031/-0032                             CRIT.  HWD:   1
.P/N VENDOR:ELD-999040                 MISSIONS:  NF  VF X FF   OF   SM
.QUANTITY  :2                          PHASE(S):  PL X LO X OO X DO X LS
.          :ONE REQ'D PER EACH         NUMBER OF SUCCESS PATHS REMAINING
.          :PROPELLANT TANK            AFTER FIRST FAILURE:              0
.                                   REDUNDANCY SCREEN:  A-N/A   B-N/A   C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES                      TIME TO EFFECT:
.PRESSURE INDICATION      V42P-1110C                     IMMEDIATE/SECONDS
.1113C                                                   REFERENCE DOCUMENTS:
.                                                        MJ070-0001-018
.GROUND TURNAROUND?.............YES                      SD72-SH-0103-2
.SAME AS FLIGHT                                          VS70-421001
.
.
.
.              PREPARED BY:                        APPROVED BY:
.                   DES          J TAGGART             DES  _____________
.                   REL            R DIEHL             REL  _____________
.
.
.ITEM: TANK
.  HELIUM STORAGE, FILAMENT WOUND.
.FUNCTION:
.  TO STORE HELIUM AT A MAX WORKING PRESSURE OF 4000 PSI FOR
   PRESSURIZATION OF THE FWD RCS MODULE PROPELLANT SUPPLY SYSTEM.  TANK
   CONSISTS OF A DOUBLE MELT T1 LINER WITH DUPONT 49 FIBER AND EPOXY RESIN
   BONDING OVER WRAP.
.FAILURE MODE:  RUPTURE, EXTERNAL LEAK       (S)
.  RUPTURE - LARGE CRACK WHICH PROPOGATES AROUND TANK IMMEDIATELY.
   LEAKAGE - FRACTURE WHICH DOES NOT PROPOGATE TO RUPTURE.
.CAUSE(S):
.  VIBRATION, STRESS CORROSION, TEMP. RISE, FATIGUE, INADVERTENT
   OVER-PRESSURIZATION (GROUND OPS).
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A) LOSS OF PRESSURIZATION TO FUEL OR OXIDIZER.    (B) EXPLOSIVE
.  EXPANSION OF HELIUM WITHIN RCS MODULE.  (C) POTENTIAL LOSS OF
   MISSION-ABORT DECISION DEPENDANT ON EXTENT OF DAMAGE.  (D) POTENTIAL
   LOSS OF CREW/VEHICLE.
.CORRECTING ACTION:
.  NONE AVAILABLE EXCEPT POSSIBLE RESCUE IF VEHICLE STILL INTACT.
.REMARKS/HAZARDS:
.  HAZARD OF SHRAPNEL PROPAGATION, HOWEVER, UTILIZATION OF FILAMENT WOUND
   TANK MINIMIZES OR ELIMINATES THIS HAZARD.  ADDITIONAL HAZARD OF MODULE
   OVER PRESSURIZATION STILL EXISTS.  NO REDUNDANCY PROVIDED FOR THIS ITEM
   - REFERENCE HAZARD 1YXX-0302-02.
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SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101010-1 REV:11/09/78
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC: 1
.P/N RI :MC282-0082-0031/-0032 CRIT. HDW: 1
.P/N VENDOR:BLD-999040 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL X LO X OO X DO X LS
. :ONE REQ'D PER EACH
. :PROPELLANT TANK
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.
.PREPARED BY: APPROVED BY: APPROVED BY NASA:
.DES J TAGGART DES SSM (A)
.REL R DIEHL REL REL
.
.
.ITEM: TANK
. HELIUM STORAGE, FILAMENT WOUND.
.FUNCTION:
. TO STORE HELIUM AT A MAX WORKING PRESSURE OF 4000 PSI FOR PRESSURIZATION OF THE FWD RCS MODULE PROPELLANT SUPPLY SYSTEM. TANK CONSISTS OF A DOUBLE MELT TI LINER WITH DUPONT 49 FIBER AND EPOXY RESIN BONDING OVER WRAP.
.FAILURE MODE: RUPTURE, EXTERNAL LEAK (S)
. RUPTURE - LARGE CRACK WHICH PROPOGATES AROUND TANK IMMEDIATELY. LEAKAGE - FRACTURE WHICH DOES NOT PROPOGATE TO RUPTURE.
.CAUSE(S):
. VIBRATION, STRESS CORROSION, TEMP. RISE, FATIGUE, INADVERTENT OVER-PRESSURIZATION (GROUND OPS).
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PRESSURIZATION TO FUEL OR OXIDIZER. (B) EXPLOSIVE EXPANSION OF HELIUM WITHIN RCS MODULE. (C) POTENTIAL LOSS OF MISSION-ABORT DECISION DEPENDANT ON EXTENT OF DAMAGE. (D) POTENTIAL LOSS OF CREW/VEHICLE.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) FILAMENT WOUND TANKS ARE DESIGNED TO LEAK BEFORE RUPTURE WHICH LIMITS FAILURE PROPAGATION DUE TO SCHRAPNEL. INCREASED STRAIN CAPABILITY IS PROVIDED BY THE COMPRESSIVE LOAD ON AN UNPRESSURIZED LINER. THE FACTOR OF SAFETY IS 1.5 X MAX WORKING PRESSURE OF 4000 PSIG. DUAL SEALS ARE PROVIDED AT TANK FLANGE. (B) TANKS ARE SUBJECTED TO PROOF PRESSURE (1.1X WORKING PRESSURE) DURING ACCEPTANCE TESTING. QUAL TESTS INCLUDE 1000 PRESSURE CYCLES EQUAL TO 4 TIMES LIFE REQUIREMENT, 90 DAY CREEP TEST AT MAX WORKING PRESSURE PLUS RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS FOR 48 MIN IN EACH AXIS. (C) IN PROCESS INSPECTION INCLUDES RADIO GRAPHIC INSPECTION OF WELDS & FLUORESCENT PENETRATION INSPECTION FOR SURFACE FLAWS. TURNAROUND CYCLE FOR EVIDENCE OF RUPTURE. AUDIT CONDUCTED 3/9/78 VERIFIED SUPPLIER RECEIVING INSPECTION CONTROLS RAW MATERIAL AND PURCHASED COMPONENTS AND IN-HOUSE INSPECTION CONTROLS CORROSION PROTECTIVE PROVISIONS, TEST HANDLING STORAGE ENVIRONMENTS, MEASUREMENT STANDARDS, TEST EQUIPMENT, NDE TESTING, PARTS PROTECTION, MFG PROCESSES AND FINISHES. CHEMICAL ETCHING, X-RAY AND PROOF TEST OF LINER AND MECHANICAL PROPOERTIES AFTER HEAT TREAT ALSO VERIFIED BY INSPECTION. (D) NO HISTORY AVAILABLE. TANK IS BEING DEVELOPED FOR SHUTTLE PROGRAM.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101013-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Helium Feedline FAILURE MODE External Leakage

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X]	*1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. GAX will give a class 2 alert upon sensing an out-of-tolerance condition. (<500 psi) Gross leak detection will give a class 2 alert.

8. Backup flight system same as primary.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO C3-2F -101013-1 REV:11/09/7.
.ASSEMBLY :PRESSURIZATION HELIUM - ABORT: CRIT. FUNC: 1
.P/N RI :V070-421701 CRIT. HW: 1
.P/N VENDOR: MISSIONS: HF VF X FF CF SM
.QUANTITY :2 PHASE(S): PL X LO X OO X DO X LS X
. :ONE SET PER PROPELLANT NUMBER OF SUCCESS PATHS REMAINING
. : AFTER FIRST FAILURE: 0
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.HELIUM TANK PRESSURE DRO P AT OFF-NOMINAL RATE; IMMEDIATE
.V42P-1110C;1112C;1113C; 1114C REFERENCE DOCUMENTS:
.
.GROUND TURNAROUND?.....YES MJ070-0001-01B
.SAME AS FLIGHT INSTRUMEN TATION SD72-SH-0103-2
. V070-421001
.
.
. PREPARED BY: APPROVED BY:
. DES A SIEGELIN DES _____
. REL R DIEHL REL _____
.
.
.ITEM: HELIUM FEED LINE AND
. FLUID FITTINGS.
.FUNCTION:
. TO PROVIDE FEED LINE FROM HELIUM TANKS TO HELIUM
REGULATION/PRESSURATION SYSTEM AND TO PROPELLANT
TANKS.
.FAILURE MODE: EXTERNAL LEAKAGE (S)
.
.CAUSE(S):
. MECHANICAL SHOCK, VIBRATION/FATIGUE, IMPROPER INSTALLATION (WELD).
FLUID FITTING SEAL FAILURE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF HELIUM SUPPLY IF NOT ISOLATABLE. (IE. IF UPSTREAM OF
. SOLENOID VALVE). (B) POTENTIAL OVERPRESSURIZATION OF FORWARD MODULE
FROM GROSS LEAK. (C,D) POTENTIAL MODULE DAMAGE RESULTING IN LOSS OF
MISSION/CREW/VEHICLE IF GROSS LEAK OCCURS DURING CRITICAL MANEUVERS.
.CORRECTING ACTION:
. INITIATE ABORT. CHECK VALVES MAINTAIN PROPELLANT TANK RESIDUAL GAS
PRESSURE TO ALLOW POTENTIAL BLOW DOWN MODE UTILIZATION.
.REMARKS/HAZARDS:
. NO REDUNDANCY PROVIDED FOR LINES. IF LEAK RATE IS EXCESSIVE PRESSURE
BUILD-UP IN MODULE MAY RESULT IN HAZARD. SEE HAZARD IYXX-0302-02.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101013-1 REV:11/09/7
.ASSEMBLY :PRESSURIZATION HELIUM - ABORT: CRIT. FUNC: 1
.P/N RI :V070-421701 CRIT. HDW: 1
.P/N VENDOR: MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL X LO X CO X DO X LS X
. :ONE SET PER PROPELLANT
. :

REDUNDANCY SCREEN: A-N/A B-N/A C-N/A

.PREPARED BY:. APPROVED BY: APPROVED BY (NASA):
.DES A SIEGELIN DES SSM
.REL R DIEHL REL REL

APPROVED WITH CHANGES
See Section 13.0

.ITEM: HELIUM FEED LINE AND
. FLUID FITTINGS.
.FUNCTION:
. TO PROVIDE FEED LINE FROM HELIUM TANKS TO HELIUM REGULATION/PRESSURATION SYSTEM AND TO PROPELLANT TANKS.
.FAILURE MODE: EXTERNAL LEAKAGE (S)

.CAUSE(S):
. MECHANICAL SHOCK, VIBRATION/FATIGUE, IMPROPER INSTALLATION (WELD). FLUID FITTING SEAL FAILURE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF HELIUM SUPPLY IF NOT ISOLATABLE. (IE. IF UPSTREAM OF SOLENOID VALVE). (B) POTENTIAL OVERPRESSURIZATION OF FORWARD MODULE FROM GROSS LEAK. (C,D) POTENTIAL MODULE DAMAGE RESULTING IN LOSS OF MISSION/CREW/VEHICLE IF GROSS LEAK OCCURS DURING CRITICAL MANEUVERS.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) FACTOR OF SAFETY OF 4.0 WILL MINIMIZE FAILURE POTENTIAL. FLUID FITTINGS HAVE DUAL SEALS. WELD CONSTRUCTION REDUCES JOINTS AND POSSIBLE LEAK PATHS. FASTENING CLAMPS AND TUBE BEND DESIGN ALLOWS DEGREE OF MOVEMENT WHICH HELPS PREVENTING LEAKS. (B) POST INSTALLATION TEST AND OPERATIONAL CHECKOUTS WILL VERIFY SYSTEM INTEGRITY. ALL LINES SUBJECTED TO 1.25 PROOF TEST. (C) IN PROCESS INSPECTION INCLUDES NDT & LEAK CHECKS DURING INSTALLATION. TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TESTS DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS. WHERE ACCESSABLE VISUALLY INSPECT FOR DAMAGE. HARDWARE INSPECTION IN ACCORDANCE WITH PLANNING RQMTS APPROVED BY NASA. (D) MINOR FAILURE HISTORY-CORROSION AND FAB PROBLEMS REPORTED DURING APOLLO PROGRAM AND CORRECTED.
WITH APPLICABLE TMO/TPC REQUIREMENT. HARDWARE INSPECTION IN ACCORDANCE WITH PLANNING RQMTS APPROVED BY NASA. (D) MINOR FAILURE HISTORY-CORROSION AND FAB PROBLEMS REPORTED DURING APOLLO PROGRAM AND CORRECTED.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101020-3

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM D. C. Solenoid Valve - Helium FAILURE MODE Fails to Close

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES ☐	NO ☒
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES ☐	NO ☐
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES ☐	*NO ☒
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES ☐	NO ☒
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES ☐	NO ☒
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES ☐	NO ☒
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES ☐	NO ☒
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 ☐	*1 ☐ 2 ☒
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A ☐	YES ☒ NO ☐
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES ☒	*NO ☐
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES ☒	*NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☒ NO H/S ISSUES
2. ☐ HARDWARE ACCEPTS RISK
3. ☐ NO SOFTWARE DETECTION
4. ☐ DETECTION DURING CHECKOUT
5. ☐ ACCEPTANCE RATIONALE BELOW
6. ☐ RECOMMENDED CHANGES BELOW

In-Flight Detectability
☒ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Switch scan will detect failure in OPS-2 only and only on demand. May not be used on STS-1.

```
 SUBSYSTEM :FWD - REACTION CONTROL     FMEA NO 03-2F -101020-3     REV:03/06/7.
.ASSEMBLY  :PRESSURIZATION             ABORT:                CRIT. FUNC:
.P/N RI    :MC284-0419-0011/-0012                            CRIT. HWD:   3
.P/N VENDOR:75835                      MISSIONS:  MF   VF X FF   OF   SM
.QUANTITY  :4                          PHASE(S):  PL X LO X OO X DO X LS
.          :TWO REQ'D PER PRESSURANT   NUMBER OF SUCCESS PATHS REMAINING
.          :FEED ASSEMBLY              AFTER FIRST FAILURE:              2
.                                   REDUNDANCY SCREEN:  A-PASS  B-PASS  C-PASS
.FAILURE DETECTABLE IN FLIGHT?. YES                    TIME TO EFFECT:
.HELIUM TANK PRESS, V42P  1110,1112,1113,1114,         SECONDS
.AND PRESS LINE;V42P1115, 1116 AND POSITION IND.       REFERENCE DOCUMENTS:
.1120X,1122X,1124X,1126X                               VL70-000245
.GROUND TURNAROUND?.............YES                    MJ070-0001-0016
.SAME AS FLIGHT INSTR.                                 SD72-SH-0105-2
.                                                      VS70-421001
.
.
.
.              PREPARED BY:                        APPROVED BY:
.                   DES          R BURKHART            DES  _____________
.                   REL          R DIEHL               REL  _____________
.
.
.ITEM: VALVE,D.C. SOLENOID
.  OPERATED, HIGH PRESSURE.  HE (3600-4000 PSIA) SOLENOID ACTUATED,
   BI-STABLE, (1/2") (LV 101/102/103/104).
.FUNCTION:
.  THESE VALVES ARE UTILIZED TO CONTROL HELIUM PRESSURIZATION OF THE RCS
   MODULE.  IN THE OPEN POSITION A FLOW PATH IS PROVIDED FROM THE HELIUM
   SUPPLY TANK(S) TO THE REGULATOR(S).  TWO PARALLEL PATHS ARE PROVIDED
   FOR FUEL AND OXIDIZER.  ONE PATH IS NORMALLY OPEN PER TANK.  THE VALVE
   IS CLOSED AND PARALLEL VALVE OPENED SUBSEQUENT TO A DOWN STREAM
   FAILURE.
.FAILURE MODE:  FAILS TO CLOSE                 (F)
.  WHEN COMMANDED TO ISOLATE DOWNSTREAM FAILURES
.CAUSE(S):
.  CONTAMINATION, VIBRATION, LOSS OF ELECTRICAL INPUT, IMPROPER OPENING
   ACTUATION, PIECE PART FAILURE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A,C,D) NO EFFECT, VALVE IS FUNCTIONED (CLOSED) ONLY SUBSEQUENT TO A
.  2ND ORDER FAILURE.  (B) NO EFFECT, DOES NOT INTERFACE WITH OTHER
   SUBSYSTEMS.
.CORRECTING ACTION:
.  NONE -
.REMARKS/HAZARDS:
.  NONE.
```

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101020-4

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM D. C. Solenoid Valve - Helium FAILURE MODE Fails Closed

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X] NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ] NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X] *NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ] NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ] NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ] NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ] NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ] *1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ] YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X] *NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X] *NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Switch scan will detect failure in OPS-2 only and only on demand. May not be used on STS-1.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101020-4 REV:12/08/7
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC: 1R
.P/N RI :MC284-0419-0011/-0012 CRIT. HWD: 2
.P/N VENDOR:73835 MISSIONS: MF VF X FF OF SM
.QUANTITY :4 PHASE(S): PL X LO X OO X DO X LS
. :TWO REQ'D PER PRESSURANT NUMBER OF SUCCESS PATHS REMAINING
. :FEED ASSEMBLY AFTER FIRST FAILURE: 1
. REDUNDANCY SCREEN: A-PASS B-PASS C-FAI
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.MONITOR TANK PRESSURE AND POSITION INDICATION MINUTES
.V42X-1120X,1122X,1124X, 1126X REFERENCE DOCUMENTS:
. VL70-008249
.GROUND TURNAROUND?.....YES MJ070-0001-015
.SAME AS FLIGHT INSTR. SD72-SH-0103-2
. VS70-421001

. PREPARED BY: APPROVED BY:
. DES , R BURKHART DES _____
. REL R DIEHL REL _____

.ITEM: VALVE,D.C. SOLENOID (Helium - Pressurization System)
. OPERATED, HIGH PRESSURE. HE (3600-4000 PSIA) SOLENOID ACTUATED, BI-STABLE,.(1/2") (LV 101/102/103/104).
.FUNCTION:
. THESE VALVES ARE UTILIZED TO CONTROL HELIUM PRESSURIZATION OF THE RCS MODULE. IN THE OPEN POSITION A FLOW PATH IS PROVIDED FROM THE HELIUM SUPPLY TANK(S) TO THE REGULATOR(S). TWO PARALLEL PATHS ARE PROVIDED FOR FUEL AND OXIDIZER. ONE PATH IS NORMALLY OPEN PER TANK. THE VALVE IS CLOSED AND PARALLEL VALVE OPENED SUBSEQUENT TO A DOWN STREAM FAILURE.
.FAILURE MODE: FAILS CLOSED (F)
.
.CAUSE(S):
. VIBRATION, CONTAMINATION CONTINUOUS INADVERTENT CLOSING SIGNAL DUE TO SHORT CIRCUIT, PIECE PART FAILURE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF REDUNDANT PRESSURIZATION PATH. (B,D) NO EFFECT. (C)
. ABORT DECISION DEPENDENT ON MISSION PHASE AND BLOWDOWN CAPABILITY.
.CORRECTING ACTION:
. IF CAUSED BY VIBRATION, THE VALVE MAY BE CAPABLE OF OPENING WITH A NEW COMMAND OR, SWITCH TO PARALLEL REGULATION PATH - COMMAND PARALLEL ISOLATION VALVE OPEN.
.REMARKS/HAZARDS:
. POTENTIAL HAZARD IN ABORT SITUATION. SEE CONSOLIDATED CONTROLS FMEA NUMBER 73835 FMEA 1.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101020-4 REV:12/08/
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC: 1R
.P/N RI :MC284-0419-0011/-0012 CRIT. HDW: 2
.P/N VENDOR:73835 MISSIONS: HF VF X FF OF SM
.QUANTITY :4 PHASE(S): PL X LO X CO X DO X LS
. :TWO REQ'D PER PRESSURANT
. :FEED ASSEMBLY
. REDUNDANCY SCREEN: A-PASS B-PASS C-FA
.
.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES R BURKHART DES SSM
.REL R DIEHL REL REL
.
.
APPROVED WITH CHANGES
See Section 13.0

.ITEM: VALVE,O.C. SOLENOID
. OPERATED, HIGH PRESSURE. HE (3600-4000 PSIA) SOLENOID ACTUATED, BI-STABLE, (1/2") (LV 101/102/103/104).
.FUNCTION:
. THESE VALVES ARE UTILIZED TO CONTROL HELIUM PRESSURIZATION OF THE RCS MODULE. IN THE OPEN POSITION A FLOW PATH IS PROVIDED FROM THE HELIUM SUPPLY TANK(S) TO THE REGULATOR(S). TWO PARALLEL PATHS ARE PROVIDED FOR FUEL AND OXIDIZER. ONE PATH IS NORMALLY OPEN PER TANK. THE VALVE IS CLOSED AND PARALLEL VALVE OPENED SUBSEQUENT TO A DOWN STREAM FAILURE.
.FAILURE MODE: FAILS CLOSED (F)
.
.CAUSE(S):
. VIBRATION, CONTAMINATION CONTINUOUS INADVERTENT CLOSING SIGNAL DUE TO SHORT CIRCUIT, PIECE PART FAILURE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF REDUNDANT PRESSURIZATION PATH. (B,D) NO EFFECT. (C) ABORT DECISION DEPENDENT ON MISSION PHASE AND BLOWDOWN CAPABILITY.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) SERIES CONTROL CIRCUITRY PROVIDED TO MINIMIZE FAILURE MODE, 100 MICRON FILTER IS PROVIDED. MEDIA HAS BEEN FILTERED TO 25 MICRON PRIOR TO ENTERING TANK. SPECIAL EMPHASAS PLACED ON THE DESIGN AND LAYOUT OF SOLENOID WIRING TO PRECLUDE SHORTS. (B) QUAL TEST INCLUDES 48 MINUTES PER AXIS OF RANDOM VIBRATION AT ANTICAPTED MISSION LEVELS AND LIFE TESTING CONSISTING OF 2200 OPERATING CYCLES. ITEM IS USED DURING SYSTEM EVALUATION AT WHITE SANDS TESTING. (C) TURNAROUND INSPECTION INCLUDES MONITORING TESTS TO VERIFY ELECTRICAL POWER TO SOLENOID VALVE FOR EVIDENCE OF SHORT CIRCUIT, SUPPLIER AUDIT CONDUCTED 8-31-77 VERIFIED SUPPLIER INSPECTION EXCERCISED CONTROL OF PARTS ID, PARTS PROTECTION, MFG PROCESSES, CONTAMINATION CONTROL, AND CORROSION PROTECTION VERIFICATION. (D) THERE IS NO FAILURE HISTORY FOR THIS SPECIFIC DESIGN.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101030-1

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Helium Pressure Regulator FAILURE MODE Fails Open

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES ☐	NO ☒
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES ☐	NO ☒
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES ☒	*NO ☐
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES ☐	NO ☒
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES ☐	NO ☒
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES ☐	NO ☒
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES ☐	NO ☒
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 ☐	*1 ☐ 2 ☒
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A ☒	YES ☐ NO ☐
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES ☐	*NO ☐
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES ☐	*NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☒ NO H/S ISSUES	3. ☐ NO SOFTWARE DETECTION	5. ☐ ACCEPTANCE RATIONALE BELOW
2. ☐ HARDWARE ACCEPTS RISK	4. ☐ DETECTION DURING CHECKOUT	6. ☐ RECOMMENDED CHANGES BELOW

☐ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Detection of this failure mode is not desired as these are redundant series regulators.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101030-1 REV:06/13/7.
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC:
.P/N RI :MC284-0418 CRIT. HW0: 3
.P/N VENDOR:74339001 MISSIONS: MF VF X FF OF SM
.QUANTITY :4 PHASE(S): PL LO X OO X DO X LS
. :TWO REQUIRED PER NUMBER OF SUCCESS PATHS REMAINING
. :PRESSURANT PATH AFTER FIRST FAILURE: 1
. REDUNDANCY SCREEN: A-PASS B-N/A C-PAS
.FAILURE DETECTABLE IN FLIGHT?. N/A TIME TO EFFECT:
.STANDBY UNIT SECONDS
. REFERENCE DOCUMENTS:
. VS70-421001
.GROUND TURNAROUND?.....YES MJ070-0001-01E
.GROUND CHECKOUT TEST PORTS SD72-SH-0103-2
.
.
.
. PREPARED BY: APPROVED BY:
. DES J. TAGGART DES _____
. REL R DIEHL REL _____
.
.
.ITEM: REGULATOR, PRESS, HE,
. SERIES REDUNDANT. SET AT UNEQUAL OUTLET PRESSURES - PRIMARY SET LOWER
  THAN SECONDARY (PR 101/102/103/104).
.FUNCTION:
. TO REGULATE STORED HELIUM PRESSURE FROM 4000 PSIG MAX TO ULLAGE
  PRESSURE OF 245 (+ OR -3) PSIG FOR PURPOSE OF PROPELLANT FEED TO
  THRUSTERS. TWO PARALLEL PATHS WITH TWO SERIES REGS ARE PROVIDED FOR
  EACH PROPELLANT TANK.
.FAILURE MODE: FAILS OPEN (F)
. OR LEAKS INTERNALLY.
.CAUSE(S):
. CONTAMINATION, VIBRATION, PIECE PART STRUCTURAL FAILURE-FLEXURES,
  BELLOWS, POPPET ASSY.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF ONE REGULATOR ELEMENT IN ONE PATH (PRIMARY) AND RISE IN
. PROPELLANT FEED PRESSURE TO SECONDARY REGULATOR ELEMENT PRESSURE
  SETTING. (S,C,D) NONE.
.CORRECTING ACTION:
. NONE REQUIRED - SERIES REGULATOR ELEMENT WILL AUTOMATICALLY TAKE OVER
  FUNCTION.
.REMARKS/HAZARDS:
. SEE FAIRCHILD FMEA # RR74339-12.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101030-2

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Helium Pressure Regulator FAILURE MODE Fails Closed

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [ ]	*NO [X]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [X] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

FMEA should be changed from"NA" to "yes" for in-flight detectability via V42P1115C and 1116C.

[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. V42P1115C, 1116C, will sense the pressure drop initiating a class 2 alarm from GAX.

2. Failure is "hardware detectable" by V42P1115C and V42P1116C pressure drop.

6. Upon regulator failure the redundant parallel "leg" can be utilized.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101030-2 REV:11/13/7
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC: 1R
.P/N R1 :MC284-0418 CRIT. HWD: 2
.P/N VENDOR:74339001 MISSIONS: HF VF X FF OF SM
.QUANTITY :4 PHASE(S): PL LO X GO X DO X LS
. :TWO REQUIRED PER NUMBER OF SUCCESS PATHS REMAINING
. :PRESSURANT PATH AFTER FIRST FAILURE: 1
. REDUNDANCY SCREEN: A-PASS B-PASS C-PASS
.FAILURE DETECTABLE IN FLIGHT?. NA TIME TO EFFECT:
.STANDBY REDUNDANCY MINUTES
. REFERENCE DOCUMENTS:
. VS70-421001
.GROUND TURNAROUND?.....YES MJ070-0001-01E
.GROUND CHECKOUT TEST PORTS SD72-SH-0103-2
.
.
.
. PREPARED BY: APPROVED BY:
. DES J. TAGGART DES _____
. REL R DIEHL REL _____
.
.
.ITEM: REGULATOR, PRESS, HE,
. SERIES REDUNDANT. SET AT UNEQUAL OUTLET PRESSURES - PRIMARY SET LOWER THAN SECONDARY (PR 101/102/103/104).
.FUNCTION:
. TO REGULATE STORED HELIUM PRESSURE FROM 4000 PSIG MAX TO ULLAGE PRESSURE OF 245 (+ OR -3) PSIG FOR PURPOSE OF PROPELLANT FEED TO THRUSTERS. TWO PARALLEL PATHS WITH TWO SERIES REGS ARE PROVIDED FOR EACH PROPELLANT TANK.
.FAILURE MODE: FAILS CLOSED (F)
. (LOW PRESSURE)
.CAUSE(S):
. CONTAMINATION (PARTIAL BLOCKAGE OF PILOT SCREEN) FROZEN MOISTURE PIECE PART FAILURE, VIBRATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF ONE REGULATOR PATH. (B,C) POTENTIAL ABORT BECAUSE ONE
. ADDITIONAL FAILURE MAY CAUSE LOSS OF PRESSURIZATION AND SUBSEQUENT VEHICLE LOSS. (D) NONE. (E) FUNCTIONAL CRITICALITY EFFECTS - IF FAILURE OCCUR BEFORE ET SEPARATION, LOSS OF HELIUM WOULD PREVENT ET SEPARATION AND LOSS OF CREW/VEHICLE WOULD RESULT.
.CORRECTING ACTION:
. CLOSE HIGH PRESSURE ISOLATION VALVE IN EFFECTED PATH AND OPEN HIGH PRESSURE ISOLATION VALVE IN PARALLEL PATH.
.REMARKS/HAZARDS:
. POTENTIAL ABORT BECAUSE ONE ADDITIONAL FAILURE (CLOSED) MAY CAUSE LOSS OF PRESSURIZATION AND SUBSEQUENT VEHICLE LOSS (REQUIRES 2ND ORDER FAILURE) DEPENDENT ON MISSION PHASE. SEE FAIRCHILD FMEA'S RR 74339-12.

SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101030-2 REV:11/13/75
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC: 1R
.P/N RI :MC284-0418 CRIT. HDW: 2
.P/N VENDOR:74339001 MISSIONS: HF VF X FF OF SM
.QUANTITY :4 PHASE(S): PL LO X OO X DO X LS
. :TWO REQUIRED PER
. :PRESSURANT PATH
. REDUNDANCY SCREEN: A-PASS B-PASS C-PASS
.
.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES J. TAGGART DES SSM
.REL R DIEHL REL REL
.
.
APPROVED WITH CHANGES
See Section 13.0

.ITEM: REGULATOR, PRESS, HE,
. SERIES REDUNDANT. SET AT UNEQUAL OUTLET PRESSURES - PRIMARY SET LOWER THAN SECONDARY (PR 101/102/103/104).
.FUNCTION:
. TO REGULATE STORED HELIUM PRESSURE FROM 4000 PSIG MAX TO ULLAGE PRESSURE OF 245 (+ OR -3) PSIG FOR PURPOSE OF PROPELLANT FEED TO THRUSTERS. TWO PARALLEL PATHS WITH TWO SERIES REGS ARE PROVIDED FOR EACH PROPELLANT TANK.
.FAILURE MODE: FAILS CLOSED (F)
. (LOW PRESSURE)
.CAUSE(S):
. CONTAMINATION (PARTIAL BLOCKAGE OF PILOT SCREEN) FROZEN MOISTURE PIECE PART FAILURE, VIBRATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF ONE REGULATOR PATH. (B,C) POTENTIAL ABORT BECAUSE ONE ADDITIONAL FAILURE MAY CAUSE LOSS OF PRESSURIZATION AND SUBSEQUENT VEHICLE LOSS. (D) NONE.

.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) EXPERIENCE FROM PREVIOUS REGULATOR DESIGN TO BE APPLIED TO PRECLUDE PIECE PART FAILURE AND SELF GENERATED CONTAMINATION. ALSO, 25 MICRON INTREGAL INLET FILTER PROVIDED TO MINIMIZE CONTAMINANTS. (B) QUAL TESTING INCLUDES 28 HOUR SAND AND DUST TEST, 48 MINUTES PER AXIS OF RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS AND LIFE CYCLE TESTS OF 50,000 CYCLES FOR THE MAIN STAGE AND 100,000 CYCLES FOR PILOT STAGE. (C) TURNAROUND INSPECTION INCLUDES MONITORING TESTS TO VERITY FUNCTIONAL OPERATION IS WITHIN SPECIFIED LIMITS. SUPPLIER AUDIT CONDUCTED VERIFIES WITHIN SPECIFIED LIMITS. SUPPLIER AUDIT CONDUCTED VERIFIES SUPPLIER CONTAMINATION CONTROL, AND STORAGE ENVIRONMENT. (D) NEW DESIGN FOR SHUTTLE APPLICATION. NO FAILURE HISTORY DATA AVAILABLE FOR THIS DESIGN.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101050-1

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Manual Valve FAILURE MODE Fails Closed or Open

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X] NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ] NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X] *NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ] NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ] NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ] NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ] NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X] *1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ] YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X] *NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X] *NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. If valve is cracked open V42P1115A, 1116A would alarm.

6. There are no success paths remaining after first failure.

```
 SUBSYSTEM :FWD - REACTION CONTROL      FMEA NO 03-2F -10105C-1     REV:C1/C4/7
.ASSEMBLY  :PRESSURIZATION              ABORT:                CRIT. FUNC:
.P/N RI    :MC284-0460-0001/-0002                             CRIT. HWD:   3
.P/N VENDOR:5760015, 5760016           MISSIONS:  NF   VF X FF   OF   SM
.QUANTITY  :2                          PHASE(S):  PL   LO X GO X DO X LS
.          :ONE REQ'D PER TANK         NUMBER OF SUCCESS PATHS REMAINING
.          :                          AFTER FIRST FAILURE:              C
.                                    REDUNDANCY SCREEN:  A-PASS  B-N/A   C-PASS
.FAILURE DETECTABLE IN FLIGHT?. YES                      TIME TO EFFECT:
.PROPELLANT TANK PRESSURE V42P-1210,1115,1116,1310       SECONDS TO MINUTES
.                                                        REFERENCE DOCUMENTS:
.                                                        MJC70-0001-01B
.GROUND TURNAROUND?.............YES                      SD72-SH-0103-2
.SAME AS FLIGHT                                          VS70-421001
.
.
.
.              PREPARED BY:                        APPROVED BY:
.                   DES          R. GONZALEZ          DES  _____________
.                   REL              R DIEHL          REL  _____________
.
.
.ITEM: VALVE,MANUAL-OPERATED.
.  TWO POSITION SELECTOR VALVE (WITH STRUCTURAL INTERLOCK) (MV 101/102).
.FUNCTION:
.  TO PROVIDE ISOLATION OF PROPELLANT TANK(S) FROM PRESSURE CYCLES WHILE
   PERFORMING GROUND C/O AND/OR SERVICING OF PRESSURIZATION SYSTEM.
.FAILURE MODE:  FAILS CLOSED OR OPEN          (_)
.  STRUCTURAL FAILURE.
.CAUSE(S):
.  SEVERE MECHANICAL SHOCK OR VIBRATION CAUSING DETENT MOVEMENT ON A
   DEFICIENT VALVE LOSS OF INTERLOCK BY FRACTURE OF DRIVE FINGER OR
   ROCKER, CORROSION, CONTAMINATION, IMPROPER USE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A)(B) LOSS OF FUNCTION (IN ABILITY TO PERFORM SYS C/O.   (C) LAUNCH
.  DELAY.   (D) NO EFFECT.
.CORRECTING ACTION:
.  NONE AVAILABLE.
.REMARKS/HAZARDS:
.  NO HAZARDS IDENTIFIED.
```

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101050-2

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Manual Valve FAILURE MODE Internal Leakage

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X]	*1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. If valve is cracked open V42P1115A, 1116A would alarm.

6. There are no success paths remaining after first failure.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -10105C-2 REV:01/04/7.
.ASSEMELY :PRESSURIZATION ABORT: CRIT. FUNC:
.P/N RI :MC284-0480-0001/-0002 CRIT. HWD: 3
.P/N VENDOR:5760015, 5760016 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO X OO X DO X LS
. :ONE REQ'D PER TANK NUMBER OF SUCCESS PATHS REMAINING
. : AFTER FIRST FAILURE: 0
. REDUNDANCY SCREEN: A-PASS B-N/A C-PASS
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.PROPELLANT TANK PRESSURE V42P-1210,1115,1116,1310 SECONDS TO MINUTES
. REFERENCE DOCUMENTS:
. MJ070-C001-01R
.GROUND TURNAROUND?.....YES SD72-SH-0105-2
.SAME AS FLIGHT V570-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES R. GONZALEZ DES _____
. REL R DIEHL REL _____
.
.
.ITEM: VALVE,MANUAL-OPERATED.
. TWO POSITION SELECTOR VALVE (WITH STRUCTURAL INTERLOCK) (MV 101/102).
.FUNCTION:
. TO PROVIDE ISOLATION OF PROPELLANT TANK(S) FROM PRESSURE CYCLES WHILE
   PERFORMING GROUND C/O AND/OR SERVICING OF PRESSURIZATION SYSTEM.
.FAILURE MODE: EXCESSIVE INTERNAL (_)
. LEAKAGE.
.CAUSE(S):
. SEVERE MECHANICAL SHOCK OR VIBRATION CAUSING DETENT MOVEMENT ON A
   DEFICIENT VALVE LOSS OF INTERLOCK BY FRACTURE OF DRIVE FINGER OR
   ROCKER, CORROSION, CONTAMINATION, IMPROPER USE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A,B) LOSS OF FUNCTION (IN ABILITY TO PERFORM SYS C/O). (C) LAUNCH
. DELAY. (D) NO EFFECT.
.CORRECTING ACTION:
. NONE AVAILABLE.
.REMARKS/HAZARDS:
. NO HAZARDS IDENTIFIED.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101060-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Relief Valve FAILURE MODE External Leakage Overboard

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X] NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ] NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X] *NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ] NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ] NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ] NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ] NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ] *1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ] YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X] *NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X] *NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Leakage of helium will cause a class 2 alarm.
Gross leak detection should occur first.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

```
 SUBSYSTEM :FWD - REACTION CONTROL     FMEA NO 03-2F -101060-1     REV:01/04/7
.ASSEMBLY  :PRESSURIZATION             ABORT:                CRIT. FUNC:
.P/N RI    :MC284-0421-0001/-0002                            CRIT. HWD:   3
.P/N VENDOR:5760009-101,5760010-102    MISSIONS:  NF   VF X FF   OF   SM
.QUANTITY  :2                          PHASE(S):  PL   LO X OO X DO X LS
.          :ONE REQ'D PER TANK         NUMBER OF SUCCESS PATHS REMAINING
.          :                           AFTER FIRST FAILURE:              2
.                                  REDUNDANCY SCREEN:  A-N/A   B-N/A   C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES                    TIME TO EFFECT:
.PRESSURE DECAY IN PRESS- SYSTEM V42P-1115C AND        HOURS
.1116C (TANK ULLAGE)                                   REFERENCE DOCUMENTS:
.                                                      MJ070-0001-01E
.GROUND TURNAROUND?.............YES                    SD72-SH-0103-2
.TEST PORT FOR GROUND     CHECKOUT AND BACK CHECK      VS70-421001
.
.
.
.              PREPARED BY:                      APPROVED BY:
.                   DES          R GONZALEZ          DES  _____________
.                   REL             R DIEHL          REL  _____________
.
.
.ITEM: VALVE, PRESS. RELIEF -
.  CRCKNG PRESS 315 PSIG, FULL OPEN 340 PSIG, RESEAT 310 PSIG   (RV
   101/102).
.FUNCTION:
.  RELIEF VALVE PROVIDED TO PREVENT RISE OF TANK AND LINE PRESSURES TO
   LEVELS WHICH COULD BE DETRIMENTAL TO SUBSYSTEM.
.FAILURE MODE:  EXTERNAL LEAK                  (_)
.  LEAKS OVERBOARD THRU BELLOWS & ORIFICE.
.CAUSE(S):
.  GALVANIC CORROSION, IMPROPER INSTALLATION/HANDLING, FATIGUE OR
   STRUCTURAL FAILURE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A&B) SUBSYSTEM DEGRADATION - HELIUM LEAKS OVERBOARD AT RATE CONTROLLED
.  BY ORIFICE.   (C&D) NO EFFECT UNLESS LEAK IS EXCESSIVE.
.CORRECTING ACTION:
.  MONITOR SYSTEM FOR HELIUM LOSS.
.REMARKS/HAZARDS:
.  NO HAZARD IDENTIFIED.
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HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101060-2

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Relief Valve FAILURE MODE Burst Disc Ruptures

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X] NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ] NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [ ] *NO [X]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ] NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ] NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ] NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ] NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ] *1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [X] YES [ ] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X] *NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X] *NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

In-Flight Detectability
[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. May see discrete drop in RCS quantity. V42P1115C, 1116C will give class 2 caution and warning alarm.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS — ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO C3-2F -101060-2 REV:01/04/7
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC:
.P/N RI :MC284-0421-0001/-0002 CRIT. HWD: 3
.P/N VENDOR:57600C9-101,57C0010-102 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL X LO X OO X DO X LS
. :ONE REQ'D PER TANK NUMBER OF SUCCESS PATHS REMAINING
. : AFTER FIRST FAILURE: 2
. REDUNDANCY SCREEN: A-PASS B-PASS C-PASS
.FAILURE DETECTABLE IN FLIGHT?. NO TIME TO EFFECT:
. IMMEDIATE
. REFERENCE DOCUMENTS:
. MJ070-0001-01E
.GROUND TURNAROUND?.....NO SD72-SH-0103-2
. VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES R GONZALEZ DES _____
. REL R DIEHL REL _____
.
.
.ITEM: VALVE, PRESS. RELIEF -
. CRCKNG PRESS 315 PSIG, FULL OPEN 340 PSIG, RESEAT 310 PSIG (RV 101/102).
.FUNCTION:
. RELIEF VALVE PROVIDED TO PREVENT RISE OF TANK AND LINE PRESSURES TO LEVELS WHICH COULD BE DETRIMENTAL TO SUBSYSTEM.
.FAILURE MODE: FAILS OPEN (_)
. BURST DISC RUPTURES.
.CAUSE(S):
. REGULATOR PRESSURE SURGE, INCORRECT PRESSURE SETTING, FATIGUE. EXCESS PRESSURE CYCLING, VIB, MAT'L DEFECT PROP TEMP RISES.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A,B) LOSS OF REDUNDANCY (LEAKAGE OR OPEN MODE)(MAIN POPPET PROVIDES
. REDUNDANCY). (C,D) NO EFFECT.
.CORRECTING ACTION:
. MONITOR SYSTEM FOR POTENTIAL HELIUM LOSS OR PROP, TANK PRESSURE DECREASE. REPLACE VALVE AFTER LANDING.
.REMARKS/HAZARDS:
. NO HAZARDS IDENTIFIED.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101060-3

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Relief Valve FAILURE MODE Fails to Burst

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X] NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ] NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X] *NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ] NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ] NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ] NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ] NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ] *1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [X] YES [ ] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X] *NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X] *NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Over pressurization will cause class 2 alarm; >312 psi. (GAX) V42P1115C, 1116C.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101060-2 REV:01/04/7
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC:
.P/N RI :MC284-0421-0301/-0002 CRIT. HWD: 3
.P/N VENDOR:5760009-101,5760010-102 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO X OO X DO X LS
. :ONE REQ'D PER TANK NUMBER OF SUCCESS PATHS REMAINING
. : AFTER FIRST FAILURE: 2
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.PRESSURE RISE IN HELIUM SYSTEM V42P-1115C AND SECONDS
.1116C (TANK ULLAGE PRESSURE) REFERENCE DOCUMENTS:
. MJ070-0001-01E
.GROUND TURNAROUND?.....YES S072-SH-0105-2
.TURNAROUND TEST PORT PROVIDED VS70-421001

. PREPARED BY: APPROVED BY:
. DES R GONZALEZ DES _____
. REL R DIEHL REL _____

.ITEM: VALVE, PRESS. RELIEF -
. CRCKNG PRESS 315 PSIG, FULL OPEN 340 PSIG, RESEAT 310 PSIG (RV 101/102).
.FUNCTION:
. RELIEF VALVE PROVIDED TO PREVENT RISE OF TANK AND LINE PRESSURES TO LEVELS WHICH COULD BE DETRIMENTAL TO SUBSYSTEM.
.FAILURE MODE: FAILS TO BURST (_)
. OR BURSTS AT A HIGHER THAN NOMINAL PRESSURE.
.CAUSE(S):
. IMPROPER INSTALLATION OR HANDLING DAMAGE THAT CAUSES DISC TO STICK PIECE PART FAILURE, PRESSURE BUILD UP ON REVERSE SIDE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR. (B) DEGRADATION OF INTERFACE SUBSYSTEM. PROP TANK ULLAGE PRESSURE MAY INCREASE ABOVE WORKING PRESSURE LIMITS. (C,D) NONE SEE (A) ABOVE.
.CORRECTING ACTION:
. CLOSE HELIUM ISOLATION VALVES, HOWEVER RELIEF COULD BE COMPLETED BY FIRING THRUSTERS.
.REMARKS/HAZARDS:
. NO HAZARDS, UNIT IS STANDBY - BACKUP FOR REGULATOR FAILURES. NO REDUNDANCY PROVIDED.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101060-4

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Relief Valve FAILURE MODE Opens Low

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [ ]	*NO [X]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

In-Flight Detectability
[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Leakage of helium will cause an oxidizer/fuel imbalance of 12.6 percent. May get a gross leak detection alarm.

```
 SUBSYSTEM :FWD - REACTION CONTROL      FMEA NO 03-2F -101060-4     REV:01/04/78
.ASSEMBLY  :PRESSURIZATION              ABORT:                CRIT. FUNC:
.P/N RI    :MC284-0421-0001/-0002                             CRIT. HWD:   3
.P/N VENDOR:5760009-101,5760010-102     MISSIONS:  MF   VF X FF.  OF   SM
.QUANTITY  :2                           PHASE(S):  PL   LO X OO X OO X LS
.          :ONE REQ'D PER TANK          NUMBER OF SUCCESS PATHS REMAINING
.          :                            AFTER FIRST FAILURE:              2
.                                    REDUNDANCY SCREEN:  A-      B-      C-
.FAILURE DETECTABLE IN FLIGHT?. NO                       TIME TO EFFECT:
.UNLESS EXCESSIVE PRESSUR E DROP IS EVIDENT IN           SECONDS TO DAYS
.TANKAGE                                                 REFERENCE DOCUMENTS:
.                                                        MJ070-0001-018
.GROUND TURNAROUND?.............NO                       SD72-SH-0103-2
.SAME AS FLIGHT                                          VS70-421001
.
.
.
.              PREPARED BY:                        APPROVED BY:
.                   DES          R GONZALEZ            DES  _____________
.                   REL             R DIEHL            REL  _____________
.
.
.ITEM: VALVE, PRESS. RELIEF -
.  CRCKNG PRESS 315 PSIG, FULL OPEN 340 PSIG, RESEAT 310 PSIG   (RV
   101/102).
.FUNCTION:
.  RELIEF VALVE PROVIDED TO PREVENT RISE OF TANK AND LINE PRESSURES TO
   LEVELS WHICH COULD BE DETRIMENTAL TO SUBSYSTEM.
.FAILURE MODE:  PREMATURE/ERRATIC OPERA-     (F)
.  TION, INTERNAL LEAKAGE, OPEN BELOW NOMINAL CRACKING PRESSURE.
.CAUSE(S):
.  VIBRATION, MECHANICAL SHOCK, CONTAMINATION, PIECE PART STRUCTURAL
   FAILURE OF POPPET.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A) LOSS OF HELIUM OR PROPELLANT VAPORS OVERBOARD.   (B) INABILITY TO
.  PRESSURIZE PROPELLANT TANKS IF LEAK IS EXCESSIVE.      (C) POTENTIAL
   ABORT IF EARLY IN MISSION, WOULD REQUIRE PRIOR FAILURE (BURST DISC
   OPEN).   (D) NONE.
.CORRECTING ACTION:
.  NONE.
.REMARKS/HAZARDS:
.  WOULD REQUIRE BURST DISC FAILURE BEFORE LEAKS OVERBOARD.  NO REDUNDANCY
   PROVIDED.
```

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101060-5

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Relief Valve FAILURE MODE Fails to Open

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Over pressurization will cause a class 2 alarm, V42P1115C, 1116C.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

```
 SUBSYSTEM :FWD - REACTION CONTROL     FMEA NO 03-2F -101060-B     REV:01/04/7
.ASSEMBLY  :PRESSURIZATION             ABORT:                CRIT. FUNC:
.P/N RI    :MC284-0421-0001/-0002                            CRIT. HWD:  3
.P/N VENDOR:5760009-101,5760010-102    MISSIONS:  HF   VF X FF   OF   SM
.QUANTITY  :2                          PHASE(S):  PL X LO X CO X DO X LS
.          :ONE REQ'D PER TANK         NUMBER OF SUCCESS PATHS REMAINING
.          :                           AFTER FIRST FAILURE:              0
.                                   REDUNDANCY SCREEN:  A-      B-      C-
.FAILURE DETECTABLE IN FLIGHT?. YES                    TIME TO EFFECT:
.TANK PRESSURE MONITOR    V42P-1116C,1115C,1210C,      SECONDS TO DAYS
.1310C                                                 REFERENCE DOCUMENTS:
.                                                      MJC70-0001-018
.GROUND TURNAROUND?.............YES                    SD72-SH-0103-2
.SAME AS FLIGHT                                        VS70-421001
.
.
.
.              PREPARED BY:                      APPROVED BY:
.                   DES          R GONZALEZ          DES  _____________
.                   REL             R DIEHL          REL  _____________
.
.
.ITEM: VALVE, PRESS. RELIEF -
.  CRCKNG PRESS 315 PSIG, FULL OPEN 340 PSIG, RESEAT 310 PSIG   (RV
   101/102).
.FUNCTION:
.  RELIEF VALVE PROVIDED TO PREVENT RISE OF TANK AND LINE PRESSURES TO
   LEVELS WHICH COULD BE DETRIMENTAL TO SUBSYSTEM.
.FAILURE MODE:  FAILS TO OPEN -                (F)
.  AT NOMINAL CRACKING PRESSURE
.CAUSE(S):
.  CONTAMINATION, PIECE PART STRUCTURAL FAILURE, POPPET GALLING.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A) LOSS OF RELIEF PATH.   (B,D) NONE.   (C) POTENTIAL MISSION LOSS
.  (ABORT DECISION) IF EARLY IN MISSION WOULD REQUIRE 2 PRIOR FAILURES.
.CORRECTING ACTION:
.  FIRE ALL THRUSTERS NON-PROPULSIVELY.
.REMARKS/HAZARDS:
.  POTENTIAL TANK RUPTURE ON 3RD ORDER FAILURE NO OTHER RELIEF PATH FOR
   SYSTEM.
```

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101070-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Fill Quick Disconnect, Helium FAILURE MODE Fails Open, Cap Leaks

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [ ]	*NO [X]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [X] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

In-flight detectability

[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1 & 2. V42P1110C, V42P1112C, V42P1113C and V42P1114C will detect the failure when the pressure drops to 500 psi and issue a class 3 caution and warning alert.

Gross leak indication should occur first. (12.6% Δ)

6. Capped quick disconnect provides one redundant success path.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

```
 SUBSYSTEM :FWD - REACTION CONTROL     FMEA NO 03-2F -101070-1     REV:12/15/7
.ASSEMBLY  :PRESSURIZATION             ABORT:              CRIT. FUNC:   1
.P/N RI    :MC276-0017-0402/0403                          CRIT. HWD:   1
.P/N VENDOR:75372000-0402/0403         MISSIONS:  HF   VF X FF   OF   SM
.QUANTITY  :2                          PHASE(S):  PL X LO X OO X DO X LS X
.          :ONE REQ'D PER TANK         NUMBER OF SUCCESS PATHS REMAINING
.          :                           AFTER FIRST FAILURE:              1
                                     REDUNDANCY SCREEN:  A-N/A   B-N/A   C-N/A
.FAILURE DETECTABLE IN FLIGHT?. NO                      TIME TO EFFECT:
.                                                       SECONDS TO DAYS
.                                                       REFERENCE DOCUMENTS:
.                                                       MJ070-0001-01B
.GROUND TURNAROUND?.............YES                     SD72-SH-0103-2
.VISUAL INSPECTION PRIOR  TO LAUNCH                     VS70-421001
.
.
.
.              PREPARED BY:                        APPROVED BY:
.                   DES          C SCARLETT            DES  _____________
.                   REL            R DIEHL             REL  _____________
.
.
.ITEM: DISCONNECT, QUICK FILL
.  HELIUM WITH SPRING LOADED POPPET AND STRUCTURAL END CAP (1/4").   (MD
   105/106)
.FUNCTION:
.  PROVIDES HELIUM TANK FILL POINT FOR GROUND OPERATIONS AND LOADING
   SERVICING.
.FAILURE MODE:  FAILS OPEN, CAP              (S)
.  LEAKS IN EXCESS OF ACCEPTABLE RATE.
.CAUSE(S):
.  VIBRATION, AND LOOSENING OF THE RETAINER NUT, IMPROPER HANDLING,
   MECHANICAL SHOCK.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A) LOSS OF REDUNDANCY.   (B) NONE.   (C) POTENTIAL LAUNCH DELAY
.  (MISSION LOSS) IF DETECTED.   (D) POSSIBLE LOSS OF CREW/VEHICLE IF
   FAILURE OCCURS PRIOR TO ET SEPARATION.
.CORRECTING ACTION:
.  REPLACE OR TIGHTEN END CAP ON GROUND. NONE AVAILABLE IN FLIGHT.
.REMARKS/HAZARDS:
.  BECAUSE STRUCTURAL CAP IS LOADED OVER THE DISCONNECT, THIS FAILURE MODE
   IS VERY REMOTE IN FLIGHT.
```

SUBSYSTEM :FWD - REACTION CONTROL
.ASSEMBLY :PRESSURIZATION
.P/N RI :MC276-0017-0402/0403
.P/N VENDOR:75372000-0402/0403
.QUANTITY :2
. :ONE REQ'D PER TANK
. :

FMEA NO 03-2F -101070-1 REV:12/08/78
ABORT: CRIT. FUNC: 1
CRIT. HDW: 1
MISSIONS: HF VF X FF OF SM
PHASE(S): PL X LO X OO X DO X LS X

REDUNDANCY SCREEN: A-N/A B-N/A C-N/A

.PREPARED BY:
.DES C SCARLETT
.REL R DIEHL

APPROVED BY:
DES C. Scarlett 12/13/78
REL C.E. Danner 12/15/78

APPROVED BY (NASA):
SSM
REL
APPROVED WITH CHANGES
See Section 13.0

.ITEM: DISCONNECT, QUICK FILL
. HELIUM WITH SPRING LOADED POPPET AND STRUCTURAL END CAP (1/4"). (MD 105/106)
.FUNCTION:
. PROVIDES HELIUM TANK FILL POINT FOR GROUND OPERATIONS AND LOADING SERVICING.
.FAILURE MODE: FAILS OPEN, CAP (S)
. LEAKS IN EXCESS OF ACCEPTABLE RATE.
.CAUSE(S):
. VIBRATION, AND LOOSENING OF THE RETAINER NUT, IMPROPER HANDLING, MECHANICAL SHOCK.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF REDUNDANCY. (B) NONE. (C) POTENTIAL LAUNCH DELAY (MISSION LOSS) IF DETECTED. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) CAP SEAL DESIGN DETERMINED TO BE ADEQUATE TO PRECLUDE LEAKAGE. DESIGN FACTOR OF SAFETY IS 2.0 X 4000 PSIG MAX WORKING PRESSURE. CAP PLUS COUPLING CONSTITUTES DUAL SEALING. ALL RETAINER NUTS ARE PROPERLY TORQUED TO PRECLUDE LOOSENING. (B) SEALS ARE EXPOSED TO OVER 600 CYCLES DURING DEVELOPMENT. COUPLINGS ARE SUBJECTED TO 600 OPERATIONAL CYCLES IN QUAL TEST. ALL CAPS AND COUPLING LEAK TESTED FOR 3 MIN. AT PRESSURES UP TO 1.25 MAX WORKING PRESSURE DURING ACCEPTANCE TEST. TURNAROUND LEAK CHECKS PERFORMED BEFORE EACH FLIGHT. RANDOM VIBRATION PERFORMED DURING QUAL PROGRAM. 68 MINUTES IN TWO AXES AT ANTICIPATED MISSION LEVELS. (C) TURNAROUND INSPECTION INCLUDES VISUAL INSPECTION ALL COUPLINGS THAT HAVE BEEN USED DURING TURNAROUND FOR DAMAGE PLUS INSPECTING FOR LEAKS DURING LEAK CHECKS. ALSO, PROPER BLEED SCREW TORQUE IS VERIFIED PRIOR TO REINSTALLATION OF ANY CAPS THAT HAVE BEEN REMOVED. SUPPLIER AUDIT CONDUCTED 4-5-77 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MATERIAL PARTS IDENTIFICATION, MFG PROCESSES, CONTAMINATION CONTROL, AND STORAGE ENVIRONMENTS. (D) NEW DESIGN FOR SHUTTLE APPLICATION. NO FLIGHT FAILURE HISTORY

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101070-2

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Quick Fill Disconnect, He. FAILURE MODE Fails Closed/Ground OPS

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES ☐ NO ☐
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES ☐ NO ☐
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES ☐ *NO ☐
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES ☐ NO ☐
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES ☐ NO ☐
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES ☐ NO ☐
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES ☐ NO ☐
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 ☐ *1 ☐ 2 ☐
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A ☐ YES ☐ NO ☐
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES ☐ *NO ☐
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES ☐ *NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☐ NO H/S ISSUES
2. ☐ HARDWARE ACCEPTS RISK
3. ☐ NO SOFTWARE DETECTION
4. ☐ DETECTION DURING CHECKOUT
5. ☐ ACCEPTANCE RATIONALE BELOW
6. ☐ RECOMMENDED CHANGES BELOW

☐ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Out of Scope. Ground operations only.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101070-2 REV:01/04/7.
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC:
.P/N RI :MC276-0017-0402/0403 CRIT. HWD: 3
.P/N VENDOR:75372000-0402/0403 MISSIONS: MF VF X FF DF SM
.QUANTITY :2 PHASE(S): PL X LO OO OO LS
. :ONE REQ'D PER TANK NUMBER OF SUCCESS PATHS REMAINING
. : AFTER FIRST FAILURE: 0
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. N/A TIME TO EFFECT:
. IMMEDIATE
. REFERENCE DOCUMENTS:
. MJ070-0001-J18
.GROUND TURNAROUND?.....YES SD72-SH-0103-2
.GSE FILL RATE AND HELIUM PRESSURE VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES C SCARLETT DES _____
. REL R DIEHL REL _____
.
.
.ITEM: DISCONNECT, QUICK FILL
. HELIUM WITH SPRING LOADED POPPET AND STRUCTURAL END CAP (1/4"). (MD 105/106)
.FUNCTION:
. PROVIDES HELIUM TANK FILL POINT FOR GROUND OPERATIONS AND LOADING SERVICING.
.FAILURE MODE: RESTRICTED FLOW - (F)
. FAILS CLOSED DURING GROUND FILL OPERATIONS
.CAUSE(S):
. VIBRATION/IMPROPER HANDLING WHICH CAUSES FILTER/POPPET DAMAGE IN DISCONNECT.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF OR REDUCED HELIUM FILL CAPABILITY. (B) NONE. (C) LAUNCH DELAY. (D) NONE.
.CORRECTING ACTION:
. REMOVE/REPLACE FILL VALVE OR ATTEMPT TO RECOUPLE.
.REMARKS/HAZARDS:
. NONE. NO REDUNDANCY PROVIDED FOR THIS ITEM IN THIS MODE.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101080-1

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Purge Quick Disconnect, Propellant FAILURE MODE External Leakage During Flight

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [ ]	*NO [X]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [X] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [ ]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [ ]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES	3. [ ] NO SOFTWARE DETECTION	5. [ ] ACCEPTANCE RATIONALE BELOW
2. [X] HARDWARE ACCEPTS RISK	4. [ ] DETECTION DURING CHECKOUT	6. [ ] RECOMMENDED CHANGES BELOW

[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Per backup flight system program requirements document MG038103, once a pre-set delta between the propellant quantities is reached a class 2 caution and warning light and tone will be annunciated. Also primary flight control requirements FSSR 0026A except OPS 1,6.

2. The above statement indicates in-flight detection.

6. Capped quick disconnect provides one redundant success path.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -10105C-1 REV:12/06/7
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC: 1
.P/N RI :MC276-0018 CRIT. HWD: 1
.P/N VENDOR:7630600 MISSIONS: HF VF X FF OF SM
.QUANTITY :14 PHASE(S): PL LO X OO X DO X LS
. :TWO INLETS AND FIVE NUMBER OF SUCCESS PATHS REMAINING
. :OUTLETS FOR EACH PROP AFTER FIRST FAILURE: 4
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. NO TIME TO EFFECT:
. SECONDS TO DAYS
. REFERENCE DOCUMENTS:
. MJC70-0001-01B
.GROUND TURNAROUND?.....YES SD72-SH-0103-2
.VISUAL INSPECTION VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES C SCARLETT DES _____
. REL R DIEHL REL _____
.
.
.ITEM: DISCONNECT, QCK, PURGE, VENT, PROPELLANT WITH STRUCTURAL END CAP AND SPRING LOADED POPPET (1/2"). (MD 117,118,123,124,127,137,138,147,161,162,163,164).
.FUNCTION:
. TO ALLOW GROUND PURGE OF PROPELLANT TANKS AND ASSOCIATED MANIFOLDS/LINES/THRUSTERS AFTER LANDING & PROPELLANT TANKS FILL, DRAIN & VENT
.FAILURE MODE: EXTERNAL LEAKAGE (S)
. DURING FLIGHT
.CAUSE(S):
. VIBRATION AND LOOSENING OF THE RETAINER NUT, STRUCTURAL FAILURE, PIECE PART FAILURE MECHANICAL SHOCK, IMPROPER GROUND HANDLING.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PROPELLANT FIRST ORDER FAILURE FOR LOOSE RETAINER NUT. (B) POSSIBLE FIRE/EXPLOSION IF FUEL REACTS WITH COMPLEMENTARY OXIDIZER (OR EXTREME HEAT DURING RE-ENTRY).(C) POSSIBLE LOSS OF MISSION DUE TO FLUID SEPARATION. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.
.CORRECTING ACTION:
. NONE AVAILABLE - IN FORWARD MODULE, CRITICALITY IS LESS SEVERE IF AFT MODULES OPERATIVE
.REMARKS/HAZARDS:
. POTENTIAL CORROSION OF SURROUNDING COMPONENTS. STRUCTURAL CAP CONSIDERED AS STRUCTURE.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101080-1 REV:12/08/7
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC: 1
.P/N RI :MC276-0018 CRIT. HDW: 1
.P/N VENDOR:76306000 MISSIONS: HF VF X FF OF SM
.QUANTITY :14 PHASE(S): PL LO X OO X DO X LS
. :TWO INLETS AND FIVE
. :OUTLETS FOR EACH PROP
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.

.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES C SCARLETT DES C. Scarlett 12/13/76 SSM W. Lovelace
.REL R DIEHL REL E. E. Damon 12/15/76 REL Karl Dauer
.
. APPROVED WITH CHANGES
See Section 13.0

.ITEM: DISCONNECT, QCK, PURGE,
. VENT, PROPELLANT WITH STRUCTURAL END CAP AND SPRING LOADED POPPET (1/2"). (MD 117,118,123,124,127,137,138,147,161,162,163,164).
.FUNCTION:
. TO ALLOW GROUND PURGE OF PROPELLANT TANKS AND ASSOCIATED MANIFOLDS/LINES/THRUSTERS AFTER LANDING & PROPELLANT TANKS FILL, DRAIN & VENT
.FAILURE MODE: EXTERNAL LEAKAGE (S)
. DURING FLIGHT
.CAUSE(S):
. VIBRATION AND LOOSENING OF THE RETAINER NUT, STRUCTURAL FAILURE, PIECE PART FAILURE MECHANICAL SHOCK, IMPROPER GROUND HANDLING.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PROPELLANT FIRST ORDER FAILURE FOR LOOSE RETAINER NUT. (B) POSSIBLE FIRE/EXPLOSION IF FUEL REACTS WITH COMPLEMENTARY OXIDIZER (OR EXTREME HEAT DURING RE-ENTRY).(C) POSSIBLE LOSS OF MISSION DUE TO FLUID SEPARATION. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) CAP SEAL DESIGN DETERMINED TO BE ADEQUATE TO PRECLUDE LEAKAGE. DESIGN FACTOR OF SAFETY IS 3.0 X 710 PSIG MAX WORKING PRESSURE. CAP PLUS COUPLING CONSTITUTES DUAL SEALING. ALL RETAINER NUTS ARE PROPERLY TORQUED TO PRECLUDE LOOSENING. (B) SEALS ARE EXPOSED TO OVER 500 CYCLES DURING DEVELOPMENT. COUPLINGS ARE SUBJECTED TO 600 OPERATIONAL CYCLES IN QUAL TEST. ALL CAPS AND COUPLINGS LEAK TESTED FOR 3 MINUTES AT PRESSURES UP TO MAX WORKING PRESSURE DURING ACCEPTANCE TEST. TURNAROUND LEAK CHECKS PERFORMED BEFORE EACH FLIGHT. RANDOM VIBRATION PERFORMED DURING QUAL PROGRAM. 68 MINUTES IN TWO AXES AT ANTICIPATED MISSION LEVELS. (C) TURNAROUND INSPECTION INCLUDES VISUAL INSPECTING ALL COUPLINGS USED DURING TURNAROUND FOR DAMAGE PLUS INSPECTING FOR LEAKS DURING LEAK CHECKS. ALSO, PROPER BLEED SCREW TORQUE IS VERIFIED PRIOR TO REINSTALLATION OF ANY CAPS THAT HAVE BEEN REMOVED. SUPPLIER AUDIT CONDUCTED 4-5-77 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MATERIAL PARTS IDENTIFICATION, MFG PROCESSES, CONTAMINATION CONTROL, AND STORAGE ENVIRONMENTS. (D) NEW DESIGN FOR SHUTTLE APPLICATION. NO FLIGHT FAILURE HISTORY.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101080-2

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Purge Quick Disconnect, Propellant FAILURE MODE Fails Closed/Ground Ops.

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES ☐ NO ☐
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES ☐ NO ☐
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES ☐ *NO ☐
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES ☐ NO ☐
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES ☐ NO ☐
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES ☐ NO ☐
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES ☐ NO ☐
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 ☐ *1 ☐ 2 ☐
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A ☐ YES ☐ NO ☐
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES ☐ *NO ☐
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES ☐ *NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☐ NO H/S ISSUES
2. ☐ HARDWARE ACCEPTS RISK
3. ☐ NO SOFTWARE DETECTION
4. ☐ DETECTION DURING CHECKOUT
5. ☐ ACCEPTANCE RATIONALE BELOW
6. ☐ RECOMMENDED CHANGES BELOW

☐ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Out of scope/ground operations only.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101080-2 REV:05/06/7:
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC:
.P/N RI :MC276-0018 CRIT. HWD: 3
.P/N VENDOR:763060C0 MISSIONS: HF VF X FF CF SM
.QUANTITY :14 PHASE(S): PL X LG OO DO LS
. :TWO INLETS AND FIVE NUMBER OF SUCCESS PATHS REMAINING
. :OUTLETS FOR EACH PROP AFTER FIRST FAILURE: 1
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. N/A TIME TO EFFECT:
. IMMEDIATE
. REFERENCE DOCUMENTS:
. MJC70-0001-01B
.GROUND TURNAROUND?.....YES SD72-SH-0103-2
.GSE EQUIPMENT FLOW RATE AND TANK OUTPUT VS70-421001
.PRESSURE V42F-1210C, 1310C
.
.
. PREPARED BY: APPROVED BY:
. DES C SCARLETT DES _____.
. REL R DIEHL REL _____.
.
.
.ITEM: DISCONNECT, QCK, PURGE,
. VENT, PROPELLANT WITH STRUCTURAL END CAP AND SPRING LOADED POPPET (1/2"). (MD 117,118,123,124,127,137,138,147,161,162,163,164).
.FUNCTION:
. TO ALLOW GROUND PURGE OF PROPELLANT TANKS AND ASSOCIATED MANIFOLDS/LINES/THRUSTERS AFTER LANDING & PROPELLANT TANKS FILL, DRAIN & VENT
.FAILURE MODE: FAILS CLOSED (F)
. DURING GROUND OPERATIONS
.CAUSE(S):
. CONTAMINATION PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PURGE FUNCTION. (B) NO EFFECT. (C) POTENTIAL LAUNCH DELAY. (D) NONE.
.CORRECTING ACTION:
. ATTEMPT TO REMOVE BLOCKAGE (BACK-FLOW) OR REMOVE COUPLING AND REPLACE
.REMARKS/HAZARDS:
. NONE. NO REDUNDANCY PROVIDED FOR THIS ITEM.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101090-1

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER

ITEM Test Quick Disconnect, Propellant FAILURE MODE Ext. Leakage/Flight

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [ ]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [X] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1 & 2. V42P1110C, V42P1112C and V42P1113C will detect the failure and issue class 3 alarm (system management blue light on crew-cockpit glare shield) at <500 psia.

Gross leak indication is quicker (class 2).

6. Capped quick disconnect provides one redundant success path.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101090-1 REV:11/09/7
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC: 1R
.P/N RI :ME276-0032 CRIT. HWE: 3
.P/N VENDOR:RR42670-5&7,R642900-1&3 MISSIONS: HF VF X FF OF SM
.QUANTITY :14 PHASE(S): PL LO X OO X DO X LS
. :SEVEN REQ'D FOR EACH NUMBER OF SUCCESS PATHS REMAINING
. :PROPELLANT AFTER FIRST FAILURE: 1
. REDUNDANCY SCREEN: A-PASS B-FAIL C-PASS
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.HELIUM TANK PRESSURE V42P-1110C,1112C,1113C, SECONDS TO DAYS
.1114C REFERENCE DOCUMENTS:
. MJ070-0001-01B
.GROUND TURNAROUND?.....N/A SD72-SH-0103-2
. VS70-421001

PREPARED BY: APPROVED BY:
DES C SCARLETT DES _____
REL R DIEHL REL _____

.ITEM: DISCONNECT, QUICK, TEST
. PT. (1/4") WITH SPRING LOADED POPPET AND STRUCTURAL CAP. (MD 101,102, 103,104,107,108,109,110,111,112,113,114,177 & 178).
.FUNCTION:
. TO PROVIDE ACCESS TO THE HELIUM SUPPLY SYSTEM AT VARIOUS POINTS IN THE SYSTEM: (1) RELIEF VALVES/BURST DISCS (2) REGULATORS (3) CHECK VALVES. PROVIDES FOR C/O OF PRESSURIZATION SUB-SYS COMPONENTS. COMPONENT INPUTS & OUTPUTS ARE ACCESSABLE AT HE SERVICE PANEL.
.FAILURE MODE: EXTERNAL LEAKAGE (S)
. DURING FLIGHT
.CAUSE(S):
. VIBRATION, PIECE PART STRUCTURAL FAILURE (POPPET, SEAL), MECHANICAL SHOCK.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF HELIUM PRESSURANT. (SECOND ORDER FAILURE). (B) LOSS OF PROPELLANT FEED CAPABILITY. (C) POTENTIAL LOSS OF MISSION DUE TO FLUID LOSS. (D) NONE. (E) FUNCTIONAL CRITICALITY EFFECTS - POTENTIAL LOSS OF HELIUM SUPPLY WHICH COULD RESULT IN LOSS OF VEHICLE IF THE LOSS OCCURRED BEFORE ET SEPARATION.
.CORRECTING ACTION:
. UTILIZE AFT MODULES TO ORIENT VEHICLE FOR ENTRY AND COMPLETE ABORT.
.REMARKS/HAZARDS:
. NONE.

SUBSYSTEM :FWD - REACTION CONTROL
.ASSEMBLY :PRESSURIZATION
.P/N RI :ME276-0032
.P/N VENDOR:RR42670-5&7,R642900-1&3
.QUANTITY :14
. :SEVEN REQ'D FOR EACH
. :PROPELLANT
.

FMEA NO 03-2F -101090-1 REV:11/09/
ABORT: CRIT. FUNC: 1R
CRIT. HDW: 3
MISSIONS: HF VF X FF OF SM
PHASE(S): PL LO X CO X OO X LS

REDUNDANCY SCREEN: A-PASS B-FAIL C-PA

.PREPARED BY:
.DES C SCARLETT
.REL R DIEHL

APPROVED BY:
DES C. Scarlett 12/7/5
REL C. E. Dawson 12/5/77

APPROVED W. Lundquist (NASA)
SSM
REL
APPROVED WITH CHANGES
See Section 13.0

.ITEM: DISCONNECT, QUICK, TEST
. PT. (1/4") WITH SPRING LOADED POPPET AND STRUCTURAL CAP. (MD 101,102, 103,104,107,108,109,110,111,112,113,114,177 & 178).
.FUNCTION:
. TO PROVIDE ACCESS TO THE HELIUM SUPPLY SYSTEM AT VARIOUS POINTS IN THE SYSTEM: (1) RELIEF VALVES/BURST DISCS (2) REGULATORS (3) CHECK VALVES. PROVIDES FOR C/O OF PRESSURIZATION SUB-SYS COMPONENTS. COMPONENT INPUTS & OUTPUTS ARE ACCESSABLE AT HE SERVICE PANEL.
.FAILURE MODE: EXTERNAL LEAKAGE (S)
. DURING FLIGHT
.CAUSE(S):
. VIBRATION, PIECE PART STRUCTURAL FAILURE (POPPET, SEAL), MECHANICAL SHOCK.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF HELIUM PRESSURANT. (SECOND ORDER FAILURE). (B) LOSS OF PROPELLANT FEED CAPABILITY. (C) POTENTIAL LOSS OF MISSION DUE TO FLUID LOSS. (D) NONE. (E) FUNCTIONAL CRITICALITY EFFECTS - POTENTIAL LOSS OF HELIUM SUPPLY WHICH COULD RESULT IN LOSS OF VEHICLE IF THE LOSS OCCURRED BEFORE ET SEPARATION.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY
. (A) DUAL SEALING SURFACES ON CAP WILL PRECLUDE FAILURE. EACH SEALING SURFACE INDEPENDANT OF THE OTHER DESIGN BURST PRESSURE IS TWO TIMES OPER PRESSURE. (B) EACH COUPLING PROOF TESTED TO AT LEAST 1.5 OPER PRESSURE & LEAK TESTED FOR 15 MIN DURING ACCEPTANCE TESTING. (C) AUDIT CONDUCTED ON 11-3-76 VERIFI. THAT SUPPLIER INSPECT. INCLUDES VERIFI. OF RAW MAT'L. PARTS MFG. IDENTIFICATION, AND PROTECTION, ASSY OPERATIONS, NDE EXAM OF WELDS, BRAZES, AND MAT'L AND EQUIP CONFORMANCE. TURNAROUND INSPECTION INCLUDES VISUALLY INSPECTING ALL COUPLINGS THAT HAVE BEEN USED FOR DAMAGE AND LEAKAGE. ALSO, PROPER AHC CAP TORQUE IS VERIFIED UPON REINSTALLATION OF ANY CAPS THAT HAVE BEEN REMOVED. (D) 14 NON-FLIGHT EXTERNAL LEAKAGE FAILURES EXPERIENCED ON LH/SM RCS DUE TO PROCESS DEFICIENCIES.

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER

ITEM Test Quick Disconnect, Propellant FAILURE MODE Fails Closed/Ground Ops

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES ☐ NO ☐
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES ☐ NO ☐
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES ☐ *NO ☐
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES ☐ NO ☐
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES ☐ NO ☐
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES ☐ NO ☐
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES ☐ NO ☐
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 ☐ *1 ☐ 2 ☐
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A ☐ YES ☐ NO ☐
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES ☐ *NO ☐
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES ☐ *NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☐ NO H/S ISSUES
2. ☐ HARDWARE ACCEPTS RISK
3. ☐ NO SOFTWARE DETECTION
4. ☐ DETECTION DURING CHECKOUT
5. ☐ ACCEPTANCE RATIONALE BELOW
6. ☐ RECOMMENDED CHANGES BELOW

☐ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Out of scope - ground operations only.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -101090-2 REV:03/06/7:
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC:
.P/N RI :ME276-0032 CRIT. FWD: 3
.P/N VENDOR:RR42670-5&7,R64290C-1&3 MISSIONS: MF VF X FF UF SM
.QUANTITY :14 PHASE(S): PL X LO GO DO LS
. :SEVEN REQ'D FOR EACH NUMBER OF SUCCESS PATHS REMAINING
. :PROPELLANT AFTER FIRST FAILURE: 1
. REDUNDANCY SCREEN: A-PASS B-N/A C-PAS:
.FAILURE DETECTABLE IN FLIGHT?. N/A TIME TO EFFECT:
. SECONDS TO HOURS
. REFERENCE DOCUMENTS:
. MJ070-0001-01B
.GROUND TURNAROUND?.....YES SD72-SH-0103-2
.NO PRESSURE READ-OUT V42P-1110C,1112C,1113C, VS70-42103
.1114C
.
.
. PREPARED BY: APPROVED BY:
. DES C SCARLETT DES _____
. REL R DIEHL REL _____
.
.
.ITEM: DISCONNECT, QUICK, TEST
. PT. (1/4") WITH SPRING LOADED POPPET AND STRUCTURAL CAP. (MD 101,102, 103,104,107,108,109,110,111,112,113,114,177 & 178).
.FUNCTION:
. TO PROVIDE ACCESS TO THE HELIUM SUPPLY SYSTEM AT VARIOUS POINTS IN THE SYSTEM: (1) RELIEF VALVES/BURST DISCS (2) REGULATORS (3) CHECK VALVES. PROVIDES FOR C/O OF PRESSURIZATION SUB-SYS COMPONENTS. COMPONENT INPUTS & OUTPUTS ARE ACCESSABLE AT HE SERVICE PANEL.
.FAILURE MODE: FAILS CLOSED (F)
. DURING TURN-AROUND/GROUND OPERATIONS
.CAUSE(S):
. CONTAMINATION, PIECE PART STRUCTURAL FAILURE (POPPET, SEAL).
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF TEST/CHECKOUT DATA. (B) INCREASED GROUND EQUIPMENT
. REQUIREMENTS. (C) POTENTIAL MISSION LAUNCH DELAY. (D) NONE.
.CORRECTING ACTION:
. TEST AT ALTERNATE POINT (IF AVAILABLE) OR REMOVE AND REPLACE COUPLING.
.REMARKS/HAZARDS:
. NONE.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101095-1

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Helium Quad Check Valve FAILURE MODE Fails Open

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [ ]	NO [X]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [X]	YES [ ] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [X] NO H/S ISSUES
2. [ ] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Series redundant.

6. Series redundant.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO C3-2F -1C1095-1 REV:11/09/7
.ASSEMBLY :PRESSURIZATION ABORT: CRIT. FUNC: 3
.P/N RI :MC284-0481-0001/-0002 CRIT. HWE: 3
.P/N VENDOR:RSC10500-001/-011 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO X OO X DO X LS
. :ONE PER HELIUM SUPPLY NUMBER OF SUCCESS PATHS REMAINING
. : AFTER FIRST FAILURE: 1
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. NO TIME TO EFFECT:
. MINUTES
. REFERENCE DOCUMENTS:
. MJ070-0001-C1E
.GROUND TURNAROUND?.....YES SD72-SH-0102-2
.GROUND TEST PORTS VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES R BURKHART DES _____
. REL R DIEHL REL _____
.
.
.ITEM: VALVE,QUAD,CHECK,HE
. (CV 101/102)
.FUNCTION:
. TO PRECLUDE PROPELLANT VAPORS FROM MIGRATING TO REGULATORS (FROM THE
   PROPELLANT TANK).
.FAILURE MODE: FAILS OPEN (F)
. OR FAILS TO REMAIN CLOSED (INTERNAL LEAKAGE).
.CAUSE(S):
. CONTAMINATION, VIBRATION, PIECE PART STRUCTURAL FAILURE, MECHANICAL
   SHOCK, VIBRATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF REDUNDANCY-SERIES VALVE WILL PROTECT REGULATORS FROM
. VAPORS. (B,C,D) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR. (E)
   FUNCTIONAL CRITICALITY EFFECT - POSSIBLE CONTAMINATION OF REGULATORS
   WITH PROPELLANT VAPORS IF BOTH CHECK VALVES ARE OPEN.
.CORRECTING ACTION:
. NONE AVAILABLE.
.REMARKS/HAZARDS:
. NO HAZARDS
   ACTION OF PROPELLANT VAPORS AND CONTAMINATION.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-101095-2

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Helium Quad Check Valve FAILURE MODE Fails Closed

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES ☐	NO ☒
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES ☐	NO ☐
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES ☐	*NO ☒
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES ☐	NO ☒
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)? X	*YES ☐	NO ☒
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES ☐	NO ☒
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES ☐	NO ☒
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 ☐	*1 ☒ 2 ☐
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A ☐	YES ☐ NO ☐
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES ☐	*NO ☐
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES ☐	*NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☐ NO H/S ISSUES
2. ☒ HARDWARE ACCEPTS RISK
3. ☐ NO SOFTWARE DETECTION
4. ☐ DETECTION DURING CHECKOUT
5. ☐ ACCEPTANCE RATIONALE BELOW
6. ☐ RECOMMENDED CHANGES BELOW

☐ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1 & 2. Upon using the thrusters, tank ullage pressure will decay until <200 psi which will give a class 2 caution and warning alarm.

```
 SUBSYSTEM :FWD - REACTION CONTROL      FMEA NO 03-2F -101095-2     REV:11/10/7:
.ASSEMBLY  :PRESSURIZATION              ABORT:                CRIT. FUNC:  1R
.P/N RI    :MC284-0481-0001/-0002                             CRIT. HWD:   3
.P/N VENDOR:RSC10500-001/-011          MISSIONS:  FF   VF X FF   OF   SM
.QUANTITY  :2                          PHASE(S):  PL   LO X OO X OO X LS
.          :ONE PER HELIUM SUPPLY      NUMBER OF SUCCESS PATHS REMAINING
.          :                           AFTER FIRST FAILURE:              1
.                                    REDUNDANCY SCREEN:  A-PASS  B-FAIL  C-FAI
.FAILURE DETECTABLE IN FLIGHT?. NO                       TIME TO EFFECT:
.DUE TO SMALL  P THE      LEAKAGE IS NOT DETEC-          MINUTES
.TABLE                                                   REFERENCE DOCUMENTS:
.                                                        MJC70-0001-01E
.GROUND TURNAROUND?.............YES                      SD72-SH-0103-2
.SAME AS FLIGHT INSTRUMEN TATION                         VS70-421001
.
.
.
.              PREPARED BY:                        APPROVED BY:
.                   DES          R BURKHART            DES  _____________
.                   REL             R DIEHL            REL  _____________
.
.
.ITEM: VALVE,QUAD,CHECK,HE
.  (CV 101/102)
.FUNCTION:
.  TO PRECLUDE PROPELLANT VAPORS FROM MIGRATING TO REGULATORS (FROM THE
   PROPELLANT TANK).
.FAILURE MODE:  FAILS CLOSED                  (F)
.  RESTRICTED FLOW.
.CAUSE(S):
.  PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK, ACCELERATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A) LOSS OF REDUNDANCY - PARALLEL PATH PROVIDES PRESSURANT FEED.
.  (B,C,) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR.   (D) NO EFFECT.
   (E) FUNCTIONAL CRITICAL EFFECTS - IF FAILURE OCCURS BEFORE ET SEPARATION
   ,LOSS OF DOWN FIRING THRUSTERS WILL PREVENT ET SEPARATION AND RESULT IN
   LOSS OF CREW/VEHICLE.
.CORRECTING ACTION:
.  NONE (BLOWDOWN MAY BE USED AFTER SECOND FAILURE).
.REMARKS/HAZARDS:
.  MINIMUM DELTA CRACKING PRESSURE FOR CRACKING IS NECESSARY REQUIREMENT
   TO MINIMIZE SYSTEM PRESSURE DROP TO TANKS.
```

SUBSYSTEM :FWD - REACTION CONTROL
.ASSEMBLY :PRESSURIZATION
.P/N RI :MC284-0481-0001/-0002
.P/N VENDOR:RS010500-001/-011
.QUANTITY :2
. :ONE PER HELIUM SUPPLY
. :

FMEA NO 03-2F -101095-2 REV:11/10/78
ABORT: CRIT. FUNC: 1R
CRIT. HDW: 3
MISSIONS: HF VF X FF OF SM
PHASE(S): PL LO X OO X DO X LS

REDUNDANCY SCREEN: A-PASS B-FAIL C-FAIL

.PREPARED BY:
.DES R BURKHART
.REL R DIEHL

APPROVED BY:
DES for Tom Fisher
REL C.E. Damm 12/5/78

APPROVED BY NASA:
SSM W. Kaschube
REL V.J. Faulconer
APPROVED WITH CHANGES
See Section 13.0

.ITEM: VALVE,QUAD,CHECK,HE
. (CV 101/102)
.FUNCTION:
. TO PRECLUDE PROPELLANT VAPORS FROM MIGRATING TO REGULATORS (FROM THE PROPELLANT TANK).
.FAILURE MODE: FAILS CLOSED (F)
. RESTRICTED FLOW.
.CAUSE(S):
. PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK, ACCELERATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF REDUNDANCY - PARALLEL PATH PROVIDES PRESSURANT FEED. (B,C,) NO EFFECT UNLESS MULTIPLE FAILURES OCCUR. (D) NO EFFECT. (E) FUNCTIONAL CRITICAL EFFECTS - IF FAILURE OCCURS BEFORE ET SEPARATION ,LOSS OF DOWN FIRING THRUSTERS WILL PREVENT ET SEPARATION AND RESULT IN LOSS OF CREW/VEHICLE.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) VALVE SEAT MATERIAL WILL NOT STICK CAUSING A FAILURE TO OPEN AND SPECIFIED MAXIMUM CRACKING PRESSURE IS ONLY 5 PSI. (B) CHECK VALVE TO BE CERTIFIED FOR 100,000 CYCLES WITHOUT CHANGE IN PERFORMANCE CHARACTERISTICS/ALSO, WILL CHECK OUT EACH VALVE ELEMENT (PARALLEL - SERIES) AFTER EACH FLIGHT. VALVE SUBJECTED TO 48 MIN OF 10.6 GRMS RANDOM VIBRATION PER AXIS DURING QUAL PROGRAM. (C) AN AUDIT CONDUCTED ON 1-16-78 INDICATED THAT SUPPLIER QC VERIFIED RAW MAT'L. CERTIFICATION TO SATISFY SHUTTLE DESIGN REQUIREMENTS, VERIFIED PROTECTION OF DETAIL PARTS FROM DAMAGE DURING MFG AND TEST, IN-PROCESS INSPECTION VERIFIED MFG TRAVELER SEQUENCES. TURNAROUND INSPECTION TO INCLUDE MONITORING FUNCTIONAL TESTS TO VERIFY FLOW AND CHECK FOR LEAKAGE. (D) NO FAILURE HISTORY. THIS IS A NEW DESIGN FOR SHUTTLE USE.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-102106-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Propellant Line Flex Assy. FAILURE MODE External Leakage

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X]	*1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. V42P1115C, 1116C will give a class 2 alert once pressure drops to a pre-determined low. Gross leak indication occurs first.

6. No redundancy available.

7. V42P1116C and V42P1115C goes to shared meter M2 and will show a large pressure drop for worst case (large leak).

FMEA Change - add V42P1116C to "failure detectable in flight".

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

```
 SUBSYSTEM :FWD - REACTION CONTROL      FMEA NO 03-2F -1C2106-1     REV:11/09/7.
.ASSEMBLY  :PROPELLANT FEED             ABORT:                CRIT. FUNC:   1
.P/N RI    :                                                  CRIT. HWD:    1
.P/N VENDOR:MC271-0095                  MISSIONS:  NF   VF X FF   CF   SM
.QUANTITY  :2                           PHASE(S):  PL   LO X OO X DO X LS
.          :ONE PER PROPELLANT          NUMBER OF SUCCESS PATHS REMAINING
.          :                            AFTER FIRST FAILURE:              0
.                                     REDUNDANCY SCREEN:  A-N/A   B-N/A   C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES                    TIME TO EFFECT:
.PROPELLANT TANK PRESSURE V42P-1310C AND MANIFOLD      SECONDS TO DAYS
.PRESSURE 1312C&1316C                                  REFERENCE DOCUMENTS:
.                                                      V07C-421CC1
.GROUND TURNAROUND?.............YES                    MJ070-0001-C15
.SAME AS FLIGHT INSTRUMEN TATION                       SD72-SH-0103-2
.                                                      VS7C-421CC1
.
.
.              PREPARED BY:                      APPROVED BY:
.                   DES          J. TAGGART          DES  _____________________
.                   REL             R DIEHL          REL  _____________________
.
.
.ITEM: PROP LINE FLEX ASSY
.
.FUNCTION:
.  TO PROVIDE PROPELLANT FEED TO APPROPRIATE PROPELLANT FEEDLINES.
.FAILURE MODE:  EXTERNAL LEAKAGE                (S)
.
.CAUSE(S):
.  MECHANICAL SHOCK, VIBRATION, FLOW, FATIGUE, IMPROPER INSTALLATION (WELD)
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A) LOSS OF PROPELLANTS.   (B) POTENTIAL CORROSION FROM FREE
.  PROPELLANTS IN MODULE.   (C) POTENTIAL MISSION LOSS OR ABORT DECISION.
   (D) POTENTIAL LOSS OF CREW/VEHICLE IF FAILURE RESULTS IN LOSS OF RCS
   FUNCTION BEFORE ET SEPARATION.
.CORRECTING ACTION:
.  ATTEMPT TO ISOLATE AND INITIATE ABORT IF REQ'D.
.REMARKS/HAZARDS:
.  POTENTIAL HAZARD OF FIRE/EXPLOSION FROM FREE PROPELLANTS.  SOME LEAK
   POINTS MAY NOT BE ISOLATABLE (I.E. BEFORE/UPSTREAM OF TANK ISOLATION
   VALVES) NO REDUNDANCY PROVIDED FOR LINES.  SEE HAZARD NO. 1YXX-0302-04.
```

SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -102106-1 REV:11/09/78
.ASSEMBLY :PROPELLANT FEED ABORT: CRIT. FUNC: 1
.P/N RI : CRIT. HDW: 1
.P/N VENDOR:MC271-0095 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO X OO X DO X LS
. :ONE PER PROPELLANT
. :

REDUNDANCY SCREEN: A-N/A B-N/A C-N/A

.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES J. TAGGART DES SSM
.REL R DIEHL REL REL

APPROVED WITH CHANGES
See Section 13.0

.ITEM: PROP LINE FLEX ASSY

.FUNCTION:
. TO PROVIDE PROPELLANT FEED TO APPROPRIATE PROPELLANT FEEDLINES.
.FAILURE MODE: EXTERNAL LEAKAGE (S)

.CAUSE(S):
. MECHANICAL SHOCK, VIBRATION, FLOW, FATIGUE, IMPROPER INSTALLATION (WELD)
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PROPELLANTS. (B) POTENTIAL CORROSION FROM FREE PROPELLANTS IN MODULE. (C) POTENTIAL MISSION LOSS OR ABORT DECISION. (D) POTENTIAL LOSS OF CREW/VEHICLE IF FAILURE RESULTS IN LOSS OF RCS FUNCTION BEFORE ET SEPARATION.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) STRUCTURAL MARGIN OF 2.0 WILL MINIMIZE FAILURE MODE POTENTIAL. (B) PROOF TESTED TO 1.5 TIMES WORKING PRESSURE AND 65 MINUTES OF RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS. (C) IN PROCESS INSPECTIONS X-RAY OF WELDS & PENETRANT INSPECT. TURN AROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TESTS DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS AND DAMAGE. SUPPLIER INSPECTION DEEMED TO BE SATISFACTORY BASED ON SURVEY CONDUCTED ON 4-20-77. (D) NO FAILURE HISTORY FOR THIS SPECIFIC DESIGN.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-102108-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Feedline and Fittings FAILURE MODE External Leakage

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X] NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ] NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X] *NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ] NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ] NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ] NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ] NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X] *1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ] YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X] *NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X] *NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. V42P1115C, 1116C will give a class 2 alert once pressure drops to a pre-determined low. Gross leak indication occurs first.

6. No redundancy available.

7. V42P1115C and V42P1116C goes to shared meter M2 and will show a large pressure drop for worst case (large leak).

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -102108-1 REV:12/03/7
.ASSEMBLY :PROPELLANT FEED. ABORT: CRIT. FUNC: 1
.P/N RI :V070-421001 CRIT. HWD: 1
.P/N VENDOR: MISSIONS: HF VF X FF OF SM
.QUANTITY :1 PHASE(S): PL LO X OO X OO X LS
. :ONE SET PER PROPELLANT NUMBER OF SUCCESS PATHS REMAINING
. : AFTER FIRST FAILURE: 0
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.PROPELLANT TANK PRESSURE V42P-1310C AND MANIFOLD SECONDS TO DAYS
.PRESSURE 1312C & 1316C REFERENCE DOCUMENTS:
. V070-421001
.GROUND TURNAROUND?.....YES MJ070-0001-31B
.SAME AS FLIGHT INSTRUMEN TATION SC72-SH-0103-2
. VS70-421001

. PREPARED BY: APPROVED BY:
. DES A SIEGELIN DES _____
. REL R DIEHL REL _____

.ITEM: FEEDLINE AND FITTINGS
. FROM TANK TO 1) TANK VALVES TO 2) MANIFOLD VALVES, TO 3) THRUSTERS.
.FUNCTION:
. TO PROVIDE FEED TO APPROPRIATE PROPELLANT COMPONENTS FOR THRUSTER OPERATION - 3 AXIS ACCELERATION CONTROL AND ROTATIONAL CONTROL.
.FAILURE MODE: EXTERNAL LEAKAGE (S)
.
.CAUSE(S):
. MECHANICAL SHOCK, VIBRATION/FATIGUE, STRUCTURAL FAILURE, IMPROPER INSTALLATION (WELD). FLUID FITTING SEAL FAILURE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) POTENTIAL LOSS OF PROPELLANTS. (B) POTENTIAL CORROSION FROM FREE PROPELLANTS IN MODULE. (C) POTENTIAL MISSION LOSS OR ABORT DECISION. (D) POTENTIAL LOSS OF CREW/VEHICLE IF LEAKING PROPELLANT EXPLODES DUE TO CONTACT WITH CATALYTIC AGENT OR HEAT SOURCE WITH SUBSEQUENT LOSS OF FORWARD MODULE OR IF LOSS OF PROPELLANT PROHIBITS ET SEPARATION.
.CORRECTING ACTION:
. ATTEMPT TO ISOLATE AND INITIATE ABORT IF REQ'D.
.REMARKS/HAZARDS:
. POTENTIAL HAZARD OF FIRE/EXPLOSION FROM FREE PROPELLANTS. SOME LEAK POINTS MAY NOT BE ISOLATABLE (I.E. BEFORE/UPSTREAM OF TANK ISOLATION VALVES) NO REDUNDANCY PROVIDED FOR LINES. SEE HAZARD NO. 1YXX-0302-04.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -102108-1 REV:12/08/
.ASSEMBLY :PROPELLANT FEED. ABORT: CRIT. FUNC: 1
.P/N RI :V070-421001 CRIT. HDW: 1
.P/N VENDOR: MISSIONS: HF VF X FF OF SM
.QUANTITY :1 PHASE(S): PL LO X CO X DO X LS
. :ONE SET PER PROPELLANT
. :

REDUNDANCY SCREEN: A-N/A B-N/A C-N/

.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES A SIEGELIN DES SSM
.REL R DIEHL REL REL

APPROVED WITH CHANGES
See Section 13.0

.ITEM: FEEDLINE AND FITTINGS
. FROM TANK TO 1) TANK VALVES TO 2) MANIFOLD VALVES, TO 3) THRUSTERS.
.FUNCTION:
. TO PROVIDE FEED TO APPROPRIATE PROPELLANT COMPONENTS FOR THRUSTER OPERATION - 3 AXIS ACCELERATION CONTROL AND ROTATIONAL CONTROL.
.FAILURE MODE: EXTERNAL LEAKAGE (S)
.
.CAUSE(S):
. MECHANICAL SHOCK, VIBRATION/FATIGUE, STRUCTURAL FAILURE, IMPROPER INSTALLATION (WELD). FLUID FITTING SEAL FAILURE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) POTENTIAL LOSS OF PROPELLANTS. (B) POTENTIAL CORROSION FROM FREE PROPELLANTS IN MODULE. (C) POTENTIAL MISSION LOSS OR ABORT DECISION. (D) POTENTIAL LOSS OF CREW/VEHICLE IF LEAKING PROPELLANT EXPLODES DUE TO CONTACT WITH CATALYTIC AGENT OR HEAT SOURCE WITH SUBSEQUENT LOSS OF FORWARD MODULE OR IF LOSS OF PROPELLANT PROHIBITS ET SEPARATION.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY
. (A) FACTOR OF SAFETY OF 4.0 WILL MINIMIZE FAILURE POTENTIAL. DYNATUBE FITTINGS HAVE DUAL SEALS. WELD CONSTRUCTION REDUCES JOINTS & POSSIBLE LEAK PATHS. FASTENING CLAMPS AND TUBE BEND DESIGN ALLOWS DEGREE OF MOVEMENT WHICH HELPS PREVENTING LEAKS. (B) POST INSTALLATION TEST AND OPERATIONAL CHECKOUTS WILL VERIFY SYSTEM INTEGRITY. ALL LINES SUBJECTED TO PROOF TEST OF 1.25 X MAX OPERATING PRESSURE OR 1.1 X SURGE (TRANSIT) PRESSURE WHICHEVER IS GREATER. PERFORMED TUBING CERTIFICATION PER "ORBITER TUBING VERIFICATION PLAN SD75-SH-0205". (C) IN-PROCESS INSPECT INCLUDES NDT & CHECKS DURING INSTALLATION. TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TESTS DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS. VISUALLY INSPECT FOR DAMAGE WHERE ACCESSIBLE. HARDWARE INSPECTION IN ACCORDANCE WITH PLANNING RQMTS APPROVED BY NASA (D) MINOR FAILURE HISTORY-CORROSION AND FAB PROBLEMS REPORTED DURING APOLLO PROGRAM AND CORRECTED WITH APPLICABLE TMO/TPC REQUIREMENT.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-102120-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-00016A

ITEM AC Motor Operated Valve (Tank) FAILURE MODE Fails Closed

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [X] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. "RCS JETS" light on caution and warning panel.

6. The manifolds are in parallel (2 legs) giving one redundant path.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -102120-1 REV:11/10/7
.ASSEMBLY :PROPELLANT FEED ABORT: ABORT, CRIT. FUNC: 1R
.P/N RI :MC284-0430-0007/-0008 RTLS CRIT. HWD: 2
.P/N VENDOR:5750025/5750026 MISSIONS: HF VF X FF OF SM
.QUANTITY :4 PHASE(S): PL LO X OO X DO LS
. :TWO REQ'D PER PROP TANK NUMBER OF SUCCESS PATHS REMAINING
. : AFTER FIRST FAILURE: 1
. REDUNDANCY SCREEN: A-PASS B-PASS C-PASS
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.THRUSTER CHAMBER PRESS., MANIFOLD PRESSURE MONITO SECONDS
.R V42P-1212-1216,1312- 1316,1521-1532 REFERENCE DOCUMENTS:
. MJ070-0001-01B
.GROUND TURNAROUND?.....YES S072-SM-0103-2
.SAME AS FLIGHT VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES R GONZALEZ DES _____
. REL R DIEHL REL _____
.
.
.ITEM: VLV, AC MOTOR OPERATED -
. TANK (1 1/2"). (LV 161-164).
.FUNCTION:
. 1) PROVIDES ISOLATION OF TANKS FROM MANIFOLDS. 2) PROVIDES BACK-UP SHUT-OFF/ISOLATION OF PROP MANIFOLDS AND ASSOCIATED THRUSTERS' COMPONENTS. BI-STABLE, (TANK PRESSURE-245 PSI). AC MOTOR DRIVEN 3 PHASE (2 OF 3 WILL ACTUATE VALVE) 115 TO 200 VOLTS 400 HZ.
.FAILURE MODE: FAILS CLOSED (F)
. POSITION - INCLUDES RESTRICTED FLOW TO LEVEL THAT DOES NOT ALLOW PROPER MIXTURE RATIO.
.CAUSE(S):
. VIBRATION, STRUCTURAL FAILURE. PREMATURE POWER TO MOTOR, ELECTRICAL SHORT.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PROPELLANT FLOW IN TWO MANIFOLDS AND SUBSEQUENT LOSS OF THRUSTER FUNCTION (THRUSTER BURN-THRU DUE TO OXID RICH MIXTURE). (B) POSSIBLE BURN-THRU PROPOGATION. (C) LOSS OF MISSION. ABORT DECISION. (D) POTENTIAL VEHICLE DAMAGE FROM COLLISION WITH RENDEVOUS TARGGET, AFTER SECOND FAILURE. CRIT 1 FOR RTLS ABORT.
.CORRECTING ACTION:
. UTILIZE REMAINING FORWARD THRUSTERS IN COUPLE WITH APPROPRIATE AFT THRUSTERS FOR BRAKING. DE-ORBIT WITH AFT MODULES
.REMARKS/HAZARDS:
. POTENTIAL HAZARD OF EXPLOSION IF OX VALVE FAILS. SEE PARKER FMEA & RMR 5750023.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -102120-1 REV:11/10/7
.ASSEMBLY :PROPELLANT FEED ABORT: ABORT, CRIT. FUNC: 1R
.P/N RI :MC284-0430-0007/-0008 RTLS CRIT. HDW: 2
.P/N VENDOR:5750025/5750026 MISSIONS: HF VF X FF OF SM
.QUANTITY :4 PHASE(S): PL LO X OO X OO LS
. :TWO REQ'D PER PROP TANK
. :

REDUNDANCY SCREEN: A-PASS B-PASS C-PAS

.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES R GONZALEZ DES SSM
.REL R DIEHL REL REL

APPROVED WITH CHANGES
See Section 13.0

.ITEM: VLV, AC MOTOR OPERATED -
. TANK (1 1/2"). (LV 161-164).
.FUNCTION:
. 1) PROVIDES ISOLATION OF TANKS FROM MANIFOLDS. 2) PROVIDES BACK-UP SHUT-OFF/ISOLATION OF PROP MANIFOLDS AND ASSOCIATED THRUSTERS' COMPONENTS. BI-STABLE, (TANK PRESSURE-245 PSI). AC MOTOR DRIVEN 3 PHASE (2 OF 3 WILL ACTUATE VALVE) 115 TO 200 VOLTS 400 HZ.
.FAILURE MODE: FAILS CLOSED (F)
. POSITION - INCLUDES RESTRICTED FLOW TO LEVEL THAT DOES NOT ALLOW PROPER MIXTURE RATIO.
.CAUSE(S):
. VIBRATION, STRUCTURAL FAILURE. PREMATURE POWER TO MOTOR, ELECTRICAL SHORT.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PROPELLANT FLOW IN TWO MANIFOLDS AND SUBSEQUENT LOSS OF THRUSTER FUNCTION (THRUSTER BURN-THRU DUE TO OXID RICH MIXTURE). (B) POSSIBLE BURN-THRU PROPOGATION. (C) LOSS OF MISSION. ABORT DECISION. (D) POTENTIAL VEHICLE DAMAGE FROM COLLISION WITH RENDEVOUS TARGGET, AFTER SECOND FAILURE. CRIT 1 FOR RTLS ABORT.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) VALVES ARE ALWAYS OPEN. DUAL SERIES SWITCHES WILL PRECLUDE SINGLE FAILURE PREMATURE ACTUATION. SHORTED RPC WILL NOT CLOSE VALVE. (B) EACH VALVE IS SUBJECTED TO ACCEPT TEST VIBRATION. VALVE IS SUBJECTED TO 48 MIN OR RANDOM VIB IN EACH AXIS AT ANTICIPATED MISSION LEVELS AND AN ENDURANCE TEST EQUIV. TO 100 MISSIONS DURING THE QUAL TEST PROGRAM. EACH VALVE SUBJECTED TO PROOF PRESSURE OF 1500 PSIG. MORE THAN 4 X WORKING PRESSURE. (C) AUDIT CONDUCTED 7-1-76 VERIFY SUPPLIER INSPECTION CONTROL OF PARTS ID AND PROTECTION, MFG PROCESSES, ELECT TERMINATIONS. TURNAROUND INSPECTION INCLUDES MONITORING TEST TO VERIFY ELECTRICAL POWER TO VALVE FOR EVIDENCE OF SHORT CIRCUITY. (D) NO FLIGHT FAILURE EXPERIENCE.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-102150-1

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Quick Disconnect FAILURE MODE External Leakage

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [X] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. The tank pressure drop (worst case/full open) will be detected by V42P1115C, 1116C; unless regulated the gross leak indication will detect it. Also measurements 1313C, and 1314C appear obsolete and should be removed from the FMEA.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -10215C-1 REV:12/08/7:
.ASSEMBLY :PROPELLANT ABORT: CRIT. FUNC: 1
.P/N RI :MC276-0018 CRIT. HWD: 1
.P/N VENDOR:763010CC MISSIONS: HF VF X FF OF SM
.QUANTITY :6 PHASE(S): PL LO X OO X DO X LS
. : NUMBER OF SUCCESS PATHS REMAINING
. :THREE REQ PER PROPELLANT AFTER FIRST FAILURE: 1
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.LOSS OF TANK PRESSURE V42P-1310C, SECONDS TO DAYS
.1312C, 1313C; 1314C, 1315C TANK TEMP REFERENCE DOCUMENTS:
.1300 AND 1400 MJC70-0001-01B
.GROUND TURNAROUND?.....N/A SD72-SH-0103-2
. VS70-421001

. PREPARED BY: APPROVED BY:
. DES C SCARLETT DES _____
. REL R DIEHL REL _____

.ITEM: DISCONNECT, QUICK, FILL
. PROPELLANT, SPRING LOADED POPPET & STRUCTURAL CAP (MD119-126).
.FUNCTION:
. TO PROVIDE FOR DRAINING, VENTING, AND BLEEDING PROPELLANT TANKS. IN BOTH HORIZONTAL AND VERTICAL VEHICLE ORIENTATION.
.FAILURE MODE: EXTERNAL LEAKAGE (S)
. DURING FLIGHT
.CAUSE(S):
. VIBRATION, AND LOOSENING OF RETAINER NUT, PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PROPELLANT OVERBOARD (1ST ORDER FAILURE FOR LOOSE RETAINING NUT). (B) POSSIBLE FIRE/EXPLOSION IF FUEL REACTS WITH OXIDIZER (2ND ORDER) OR EXTREME HEAT DURING RE-ENTRY. (C) POSSIBLE LOSS OF MISSION DUE TO FLUID LOSS. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.
.CORRECTING ACTION:
. INITIATE ABORT OR RESCUE OPERATIONS.
.REMARKS/HAZARDS:
. POTENTIAL HAZARD FROM FIRE, EXPLOSION, AND FREE PROPELLANTS. SEE HAZARD 1YXX-0302-05.

SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -102150-1 REV:12/08/78
.ASSEMBLY :PROPELLANT ABORT: CRIT. FUNC: 1
.P/N RI :MC276-0018 CRIT. HDW: 1
.P/N VENDOR:76301000 MISSIONS: HF VF X FF OF SM
.QUANTITY :6 PHASE(S): PL LO X OO X DO X LS
. :
. :THREE REQ PER PROPELLANT
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.

.PREPARED BY: APPROVED BY: APPROVED BY (NASA)
.DES C SCARLETT DES C. Scarlett 12/13/78 SSM W. Lousma
.REL R DIEHL REL C. E. Damm 12/15/78 REL Karl Sauter
.
.
APPROVED WITH CHANGES
See Section 13.0

.ITEM: DISCONNECT, QUICK, FILL
. PROPELLANT, SPRING LOADED POPPET & STRUCTURAL CAP (MD119-126).
.FUNCTION:
. TO PROVIDE FOR DRAINING, VENTING, AND BLEEDING PROPELLANT TANKS. IN BOTH HORIZONTAL AND VERTICAL VEHICLE ORIENTATION.
.FAILURE MODE: EXTERNAL LEAKAGE (S)
. DURING FLIGHT
.CAUSE(S):
. VIBRATION, AND LOOSENING OF RETAINER NUT, PIECE PART STRUCTURAL FAILURE, MECHANICAL SHOCK.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PROPELLANT OVERBOARD (1ST ORDER FAILURE FOR LOOSE RETAINING NUT). (B) POSSIBLE FIRE/EXPLOSION IF FUEL REACTS WITH OXIDIZER (2ND ORDER) OR EXTREME HEAT DURING RE-ENTRY. (C) POSSIBLE LOSS OF MISSION DUE TO FLUID LOSS. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) CAP SEAL DESIGN DETERMINED TO BE ADEQUATE TO PRECLUDE LEAKAGE. DESIGN FACTOR OF SAFETY IS 3.0 X 710 PSIG MAX WORKING PRESSURE. CAP PLUS COUPLING CONSTITUTES DUAL SEALING. ALL RETAINER NUTS ARE PROPERLY TORQUED TO PRECLUDE LOOSENING. (B) SEALS ARE EXPOSED TO OVER 500 CYCLES DURING DEVELOPMENT. COUPLINGS ARE SUBJECTED TO 600 OPERATIONAL CYCLES IN QUAL TEST. ALL CAPS & COUPLINGS LEAK TESTED FOR 3 MIN. AT PRESSURES UP YO 1.25 MAX WORKING PRESSURE DURING ACCEPTANCE TEST. TURNAROUND LEAK CHECKS PERFORMED BEFORE EACH FLIGHT. RANDOM VIBRATION PERFORMED DURING QUAL PROGRAM. 68 MINUTES IN TWO EXES AT ANTICIPATED MISSION LEVELS. (C) TURNAROUND INSPECTION INCLUDES VISUAL INSPECTING ALL COUPLINGS THAT HAVE BEEN USED DURING TURNAROUND FOR DAMAGE PLUS INSPECTING FOR LEAKS DURING LEAK CHECKS. ALSO, PROPER BLEED SCREW TORQUE IS VERIFIED PRIOR TO REINSTALLATION OF ANY CAPS THAT HAVE BEEN REMOVED. SUPPLIER AUDIT CONDUCTED 4-5-77 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MATERIAL PARTS IDENTIFICATION, MFG PROCESSES, CONTAMINATION CONTROL, AND STORAGE ENVIRONMENTS. (D) NEW DESIGN FOR SHUTTLE APPLICATION. NO FLIGHT FAILURE HISTORY.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-102150-2

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Quick Disconnect FAILURE MODE Fails Closed/Ground Ops

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES ☐	NO ☐
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES ☐	NO ☐
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES ☐	*NO ☐
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES ☐	NO ☐
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES ☐	NO ☐
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES ☐	NO ☐
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES ☐	NO ☐
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 ☐	*1 ☐ 2 ☐
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A ☐	YES ☐ NO ☐
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES ☐	*NO ☐
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES ☐	*NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☐ NO H/S ISSUES
2. ☐ HARDWARE ACCEPTS RISK
3. ☐ NO SOFTWARE DETECTION
4. ☐ DETECTION DURING CHECKOUT
5. ☐ ACCEPTANCE RATIONALE BELOW
6. ☐ RECOMMENDED CHANGES BELOW

☐ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

Out of scope - ground operations only.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -102150-2 REV:06/27/7
.ASSEMBLY :PROPELLANT ABORT: CRIT. FUNC:
.P/N PI :MC276-0018 CRIT. HWD: 3
.P/N VENDOR:76301000 MISSIONS: HF VF X FF OF SM
.QUANTITY :6 PHASE(S): PL X LO OO OO LS
. : NUMBER OF SUCCESS PATHS REMAINING
. :THREE REQ PER PROPELLANT AFTER FIRST FAILURE: 0
. REDUNDANCY SCREEN: A-PASS B-N/A C-PASS
.FAILURE DETECTABLE IN FLIGHT?. NA TIME TO EFFECT:
. SECONDS TO HOURS
. REFERENCE DOCUMENTS:
. MJ070-0001-01B
.GROUND TURNAROUND?.....YES SD72-SH-0103-2
.GROUND EQUIPMENT FLOW RATE READ OUT VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES C SCARLETT DES _____
. REL R DIEHL REL _____
.
.
.ITEM: DISCONNECT, QUICK, FILL
. PROPELLANT, SPRING LOADED POPPET & STRUCTURAL CAP (MD119-126).
.FUNCTION:
. TO PROVIDE FOR DRAINING, VENTING, AND BLEEDING PROPELLANT TANKS. IN
   BOTH HORIZONTAL AND VERTICAL VEHICLE ORIENTATION.
.FAILURE MODE: FAILS CLOSED (F)
. DURING GROUND OPERATIONS
.CAUSE(S):
. CONTAMINATION, PIECE PART STRUCTURAL FAILURE IMPROPER HANDLING.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF FILL CAPABILITY. (B) INCREASED GROUND OPERATIONS
. REQUIREMENTS. (C) LAUNCH DELAY. (D) NONE.
.CORRECTING ACTION:
. REMOVE AND REPLACE FILL VALVE OR ATTEMPT RECONNECTION.
.REMARKS/HAZARDS:
. NONE.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-102170-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM DC Solenoid Operated Valve Vernier Thurster Manifold FAILURE MODE Fails Closed - Premature Operation

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?.	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [X] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. Manifold status on CRT and panel talk back is available.

6. One failure is all that can occur since there is no redundancy. The Shuttle can tolerate this failure since it is a criticality 3.

7. The measurements V42X1332X and V42X1232X are downlisted and available for CRT callup.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -10217C-1 REV:12/08/7.
.ASSEMBLY :PROPELLANT FEED ABORT: CRIT. FUNC: 2
.P/N RI :MC284-0420-0011/-0012 CRIT. HWD: 2
.P/N VENDOR:73895-0011/-0012 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO OG X OO LS
. :ONE REQ'D PER PROPELLANT NUMBER OF SUCCESS PATHS REMAINING
. : AFTER FIRST FAILURE: 0
. REDUNDANCY SCREEN: A-PASS B-PASS C-FAI
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.MANIFLD POSITN INDICATOR V42X1232E SECONDS
.V42X1332E REFERENCE DOCUMENTS:
. MJC70-0001-018
.GROUND TURNAROUND?.....YES SD72-SH-0103-2
.SAME AS FLIGHT VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES R BURKHART DES _____
. REL R DIEHL REL _____
.
.
.ITEM: VLVE,DC SOLEN OPERATED -
. VERNIER THRUSTER MANIFOLD, (1/4") 51-STABLE, SOLENOID DRIVEN 28VDC.
(LV 157-159)
.FUNCTION:
. TO PROVIDE ISOLATION OF PROPELLANT MANIFOLD AND ASSOCIATED VERNIER
THRUSTERS 1) SUBSEQUENT TO DOWNSTREAM FAILURE(S) 2) PRIOR TO SYSTEM
ACTIVATION.
.FAILURE MODE: FAILS CLOSED-PREMATURE (F)
. OPERATION
.CAUSE(S):
. IMPROPER ELECTRICAL SIGNAL (CONTINUOUS SHORT), PIECE PART FAILURE,
CONTAMINATION, VIBRATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF VERNIER THRUSTER FUNCTION. (B) NONE. (C) POSSIBLE EARLY
. MISSION TERMINATION. BECAUSE LARGE THRUSTERS INADEQUATE FOR SMALL RATE
ATTITUDE HOLD. (D) NONE.
.CORRECTING ACTION:
. ATTEMPT TO UTILIZE LARGE THRUSTER IN AFFECTED AXIS TO MAINTAIN SMALL
DEADBAND.
.REMARKS/HAZARDS:
. POTENTIAL FOR COLLISION WITH OR LOSS OF PAYLOAD/SATELLITE. SEE
CONSOLIDATED CONTROLS FMEA # 73895 FMEA 1.

SHUTTLE CRITICAL ITEMS LIST - CRBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -102170-1 REV:12/08/7
.ASSEMBLY :PROPELLANT FEED ABORT: CRIT. FUNC: 2
.P/N RI :MC284-0420-0011/-0012 CRIT. HDW: 2
.P/N VENDOR:73895-0011/-0012 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO OO X OO LS
. :ONE REQ'D PER PROPELLANT
. :
. REDUNDANCY SCREEN: A-PASS B-PASS C-FAI
.
.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES R BURKHART DES SSM
.REL R DIEHL REL REL
.
.
.ITEM: VLVE,DC SOLEN OPERATED -
. VERNIER THRUSTER MANIFOLD, (1/4") BI-STABLE, SOLENOID DRIVEN 28VDC. (LV 157-158)
.FUNCTION:
. TO PROVIDE ISOLATION OF PROPELLANT MANIFOLD AND ASSOCIATED VERNIER THRUSTERS 1) SUBSEQUENT TO DOWNSTREAM FAILURE(S) 2) PRIOR TO SYSTEM ACTIVATION.
.FAILURE MODE: FAIL CLOSED-PREMATURE (F)
. OPERATION
.CAUSE(S):
. IMPROPER ELECTRICAL SIGNAL (CONTINUOUS SHORT), PIECE PART FAILURE, CONTAMINATION, VIBRATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF VERNIER THRUSTER FUNCTION. (B) NONE. (C) POSSIBLE EARLY MISSION TERMINATION. BECAUSE LARGE THRUSTERS INADEQUATE FOR SMALL RATE ATTITUDE HOLD. (D) NONE.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) SERIES CONTROL CIRCUITRY PROVIDED TO MINIMIZE FAILURE MODE, 100 MICRON FILTER IS PROVIDED. MEDIA HAS BEEN FILTERED TO 25 MICRON PRIOR TO ENTERING TANK. SPECIAL EMPHASAS PLACED ON THE DESIGN AND LAYOUT OF SOLENOID WIRING TO PRECLUDE SHORTS. (B) QUAL TEST INCLUDES 48 MINUTES PER AXIS OF RANDOM VIBRATION AT ANTICAPTED MISSION LEVELS AND LIFE TESTING CONSISTING OF 2000 OPERATING CYCLES. ITEM IS USED DURING SYSTEM EVALUATION AT WHITE SANDS TESTING. (C) TURNAROUND INSPECTION INCLUDES MONITORING TESTS TO VERIFY ELECTRICAL POWER TO SOLENOID VALVE FOR EVIDENCE OF SHORT CIRCUIT, SUPPLIER AUDIT CONDUCTED 8-31-77 VERIFIED SUPPLIE INSPECTION EXCERCISED CONTROL OF PARTS ID, PARTS PROTECTION, MFG PROCESSES, CONTAMINATION CONTROL, AND CORROSION PROTECTION VERIFICATION. (D) FAILURES ON APOLLO WERE MOSTLY DUE TO CONTAMINATION RESULTING FROM IN-HOUSE PROCESSING.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-111110-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Tank Assembly and Propellant Acquisition Device FAILURE MODE Large Rupture

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?.	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [ ]	*NO [X]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X]	*1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [ ]	*NO [X]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES	3. [ ] NO SOFTWARE DETECTION	5. [ ] ACCEPTANCE RATIONALE BELOW
2. [X] HARDWARE ACCEPTS RISK	4. [ ] DETECTION DURING CHECKOUT	6. [ ] RECOMMENDED CHANGES BELOW

In-Flight Detectability
[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. V42P1115C, 1116C will give a class 2 caution and warning alert. Gross leak indication will detect failure.

If an internal rupture occurs and helium reaches the thrusters you will get a "fail off" light from redundancy management.

6. There are no redundant tanks.

8b. Backup flight system same as primary.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

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 SUBSYSTEM :FWD - REACTION CONTROL      FMEA NO 03-2F -111110-1     REV:12/19/7:
.ASSEMBLY  :PROPELLANT FEED             ABORT:                CRIT. FUNC:    1
.P/N RI    :MC282-0061-0001/0002                              CRIT. HWD:     1
.P/N VENDOR:85EC33200C0-0C9/010         MISSIONS:  HF   VF X FF   OF   SM
.QUANTITY  :2                           PHASE(S):  PL X LO X OO X DO X LS
.          :ONE REQ'D                   NUMBER OF SUCCESS PATHS REMAINING
.          :PER PROPELLANT              AFTER FIRST FAILURE:              0
.                                    REDUNDANCY SCREEN:  A-N/A   B-N/A   C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES                      TIME TO EFFECT:
.MONITOR TANK PRESSURES   V42P1310C,1312C,1316C,        SECONDS
.1116C                                                   REFERENCE DOCUMENTS:
.                                                        MJ070-0001-018
.GROUND TURNAROUND?.............YES                      SD72-SH-0103-2
.SAME AS FLIGHT                                          VS70-421001
.
.
.
.              PREPARED BY:                        APPROVED BY:
.                   DES          R BEMIS             DES  _____________
.                   REL          R DIEHL             REL  _____________
.
.
.ITEM: TANK ASSY, PROPELLANT
.  INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARRIER.   (TK
   103).
.FUNCTION:
.  TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS.
   NOMINAL STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).
.FAILURE MODE:  STRUCTURAL FAILURE -        (S)
.  TANK WALL CRACK OR RUPTURE WHICH PROPOGATES AROUND TANK
.CAUSE(S):
.  VIBRATION, OVERPRESSURIZATION, MECHANICAL SHOCK, STRESS CORROSION,
   FATIGUE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A) LOSS OF PROPELLANT SUPPLY FOR MODULE THRUSTERS.  (B) POTENTIAL
.  FIRE/EXPLOSION AND CERTAIN CONTAMINATION OF SUBSYSTEMS IN RCS
   COMPARTMENT.  (C) LOSS OF MISSION.  (D) POTENTIAL LOSS OF CREW/VEHICLE
   FROM EXPLOSION AND/OR LACK OF PROPELLANT.
.CORRECTING ACTION:
.  NONE AVAILABLE
.REMARKS/HAZARDS:
.  POTENTIAL HAZARD FROM FIRE, EXPLOSION DUE TO FREE FUEL IN MODULE.
   REFERENCE HAZARDS 1YXX-0302-02 AND 1YXX-0302-04.
```

SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -111110-1 REV:11/09/7
.ASSEMBLY :PROPELLANT FEED ABORT: CRIT. FUNC: 1
.P/N RI :MC282-0061-0001/0002 CRIT. HDW: 1
.P/N VENDOR:855C3320000-009/010 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL X LO X OO X DO X LS
. :ONE REQ'D
. :PER PROPELLANT
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.
.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES R BEMIS DES SSM
.REL R DIEHL REL REL
.
.
APPROVED WITH CHANGES
See Section 13.0

.ITEM: TANK ASSY, PROPELLANT
. INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARRIER. (TK 103).
.FUNCTION:
. TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS. NOMINAL STORAGE PRESSURE 245 PSIG +OR -15 (1.5 SAFETY FACTOR).
.FAILURE MODE: STRUCTURAL FAILURE - (S)
. TANK WALL CRACK OR RUPTURE WHICH PROPOGATES AROUND TANK
.CAUSE(S):
. VIBRATION, OVERPRESSURIZATION, MECHANICAL SHOCK, STRESS CORROSION, FATIGUE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PROPELLANT SUPPLY FOR MODULE THRUSTERS. (B) POTENTIAL FIRE/EXPLOSION AND CERTAIN CONTAMINATION OF SUBSYSTEMS IN RCS COMPARTMENT. (C) LOSS OF MISSION. (D) POTENTIAL LOSS OF CREW/VEHICLE FROM EXPLOSION AND/OR LACK OF PROPELLANT.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) DESIGN FACTR OF SAFETY IS 1.5 MIN. DEVELOPMENT TESTS INCLUDE WELD CYCLE LIFE (800 CYCLES), FRACTURE MECHANICS, FORGING EVALUATION, AND TUBE SWAGING. (B) TANKS SUBJECTED TO RADIOGRAPHIC, FLUORESCENT PENETRANT, PROOF PRESSURE (1.33 MAX OPER PRESSURE), AND EXTERNAL LEAK TESTS DURING ACCEPTANCE TESTING. TANKS SUBJECTED TO 90 DAY PROPELLANT EXPOSURE, 800 PRESSURE CYCLES, 48 MINUTES PER AXIS OF 3.9 GRMS RANDOM VIBRATION AND BURST PRESSURE DURING QUAL PROGRAM. (C) TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TEST DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS. VISUAL INSPECT WHERE ACCESSABLE FOR DAMAGE. AUDIT CONDUCTED 11-1-76 VERIFIED SUPPLIER INSPECTION CONTROL OF MATL IDENTIFICATION PARTS PROTECTION MFG PROCESSES, CORROSION PROTECTION PROVISIONS, NDE EXAM OF WELDS AND STORAGE ENVIRONMENTS. (D) NONE (NEW DEVELOPMENT ITEM).

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-111110-2

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Tank Assembly and Propellant Acquisition Device FAILURE MODE Small Crack - External Leakage

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [ ]	*NO [X]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X]	*1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [ ]	*NO [X]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

In-Flight Detectability
[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. V42P1115C, 1116C will give a class 2 caution and warning alert.
Gross leak indication will detect failure.
If an internal ruputre occurs and helium reaches the thursters you will get a "fail off" light from redundancy management.

6. There are no redundant tanks.

8b. Backup flight system same as primary.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -111110-2 REV:12/18/7
.ASSEMBLY :PROPELLANT FEED ABORT: CRIT. FUNC: 2
.P/N RI :MC282-0061-0001/0002 CRIT. HWD: 2
.P/N VENDOR:85C3320000-009/010 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL X LO X CO X DO X LS
. :ONE REQ'D NUMBER OF SUCCESS PATHS REMAINING
. :PER PROPELLANT AFTER FIRST FAILURE: 0
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.MONITOR TANK PRESSURE V42P-1310C,1312C,1316C, DAYS
.1116C REFERENCE DOCUMENTS:
. MJ070-0001-01E
.GROUND TURNAROUND?.....YES SD72-SH-0103-2
.SAME AS FLIGHT AND VISUAL OBSERVATION VS70-421601
.
.
.
. PREPARED BY: APPROVED BY:
. DES R BEMIS DES _____
. REL R DIEHL REL _____
.
.
.ITEM: TANK ASSY, PROPELLANT
. INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARRIER. (TK 103).
.FUNCTION:
. TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS. NOMINAL STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).
.FAILURE MODE: EXTERNAL LEAKAGE - (S)
. TANK CRACK OR FLAW WHICH ALLOWS A LIMITED AMOUNT OF PROPELLANT TO LEAVE THE TANK.
.CAUSE(S):
. VIBRATION, STRESS CORROSION, PRESSURE CYCLES, FATIGUE OR FLANGE SEAL FAILURE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF A QUANTITY OF PROPELLANT AND HELIUM TO AN EXTENT DEPENDENT
. ON SIZEAND LOCATION OF LEAK. (B) CONTAMINATION OF SURROUNDING AREA AND SUBSYSTEMS. (C) LOSS OF MISSION. (D) POTENTIAL EXPLOSION AND LOSS OF CREW/VEHICLE IF IGNITION SOURCE PRESENT (SECOND FAILURE).
.CORRECTING ACTION:
. CLOSE HELIUM PRESSURIZATION ISOLATION VALVE TO MINIMIZE AMOUNT OF PROPELLANT/HELIUM LOST.
.REMARKS/HAZARDS:
. POTENTIAL HAZARD FROM FREE PROPELLANT IN MODULE. NO REDUNDANCY PROVIDED FOR THIS ITEM. REFERENCE HAZARD 1YXX-0302-05.

SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -111110-2 REV:11/10/79
.ASSEMBLY :PROPELLANT FEED ABORT: CRIT. FUNC: 2
.P/N RI :MC282-0061-0001/0002 CRIT. HDW: 2
.P/N VENDOR:855C3320000-009/010 MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL X LO X OO X DO X LS
. :ONE REQ'D
. :PER PROPELLANT
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.

.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES R BEMIS DES SSM
.REL R DIEHL REL REL

APPROVED WITH CHANGES
See Section 13.0

.ITEM: TANK ASSY, PROPELLANT
. INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARRIER. (TK 103).
.FUNCTION:
. TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS. NOMINA STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).
.FAILURE MODE: EXTERNAL LEAKAGE - (S)
. TANK CRACK OR FLAW WHICH ALLOWS A LIMITED AMOUNT OF PROPELLANT TO LEAVE THE TANK.
.CAUSE(S):
. VIBRATION, STRESS CORROSION, PRESSURE CYCLES, FATIGUE OR FLANGE SEAL FAILURE.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF A QUANTITY OF PROPELLANT AND HELIUM TO AN EXTENT DEPENDENT ON SIZEAND LOCATION OF LEAK. (B) CONTAMINATION OF SURROUNDING AREA AND SUBSYSTEMS. (C) LOSS OF MISSION. (D) POTENTIAL EXPLOSION AND LOSS OF CREW/VEHICLE IF IGNITION SOURCE PRESENT (SECOND FAILURE).
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) DESIGN FACTR OF SAFETY IS 1.5 MIN. DEVELOPMENT TESTS INCLUDE WELD CYCLE LIFE (800 CYCLES), FRACTURE MECHANICS, FORGING EVALUATION, AND TUBE SWAGING. (B) TANKS SUBJECTED TO RADIOGRAPHIC, FLUORESCENT PENETRANT, PROOF PRESSURE (1.33 MAX OPER PRESSURE), AND EXTERNAL LEAK TESTS DURING ACCEPTANCE TESTING. TANKS SUBJECTED TO 90 DAY PROPELLANT EXPOSURE, 600 PRESSURE CYCLES, 48 MINUTES PER AXIS OF 3.9 GRMS RANDOM VIBRATION AND BURST PRESSURE DURING QUAL PROGRAM. (C) TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TEST DURING PRESSURIZATION CYCLE FOR EVIDENCE OF LEAKS. VISUAL INSPECT WHERE ACCESSABLE FOR DAMAGE. AUDIT CONDUCTED 11-1-76 VERIFIED SUPPLIER INSPECTION CONTROL OF MATL IDENTIFICATION PARTS PROTECTION MFG PROCESSES, CORROSION PROTECTION PROVISIONS, NDE EXAM OF WELDS AND STORAGE ENVIRONMENTS. (D) NONE (NEW DEVELOPMENT ITEM).

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-111110-3

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Tank Assembly and Propellant Acquisition Device FAILURE MODE Restricted Flow

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [ ]	*NO [X]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X]	*1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [ ]	*NO [X]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. "Fail Off" detection in RCS RM.

6. No redundant tanks.

7. No correcting action - abort.

8b. Same as primary.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

```
 SUBSYSTEM :FWD - REACTION CONTROL      FMEA NO 03-2F -111110-3     REV:12/18/7
.ASSEMBLY  :PROPELLANT FEED             ABORT:                CRIT. FUNC:   1
.P/N RI    :MC282-0061-0001/0002                              CRIT. HWC:    1
.P/N VENDOR:655C3320C0C-0C9/01C         MISSIONS:  MF   VF X FF   OF   SM
.QUANTITY  :2                           PHASE(S):  PL   LO X OO X DO X LS
.          :ONE REQ'D                   NUMBER OF SUCCESS PATHS REMAINING
.          :PER PROPELLANT              AFTER FIRST FAILURE:              0
.                                     REDUNDANCY SCREEN:  A-N/A   B-N/A   C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES                      TIME TO EFFECT:
.ENGINE PERFORMANCE                                      SECONDS TO DAYS
.                                                        REFERENCE DOCUMENTS:
.                                                        MJ070-C001-C18
.GROUND TURNAROUND?.............NO                       SD72-SH-C103-2
.                                                        VS70-42100C1
.
.
.
.              PREPARED BY:                        APPROVED BY:
.                   DES          R BEMIS              DES  _____________________
.                   REL          R DIEHL              REL  _____________________
.
.
.ITEM: TANK ASSY, PROPELLANT
.  INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARRIER.   (TK
   103).
.FUNCTION:
.  TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS.
   NOMINAL STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).
.FAILURE MODE:  RESTRICTED FLOW -          (S)
.  STRUCTURAL FAILURE OF PROPELLANT ACQUISITION DEVICE WHICH BLOCKS OR
   RETARDS RATE OF FLOW OF PROPELLANT INTO TANK OUTLET.
.CAUSE(S):
.  VIBRATION, MECHANICAL SHOCK, EXCESSIVE FLOW RATES DUE TO EXCESSIVE GAS
   IN THRUSTER MANIFOLD.  (SEE FAILURE MODE NO. 4 ON NEXT PAGE).
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A) LOSS OF FULL PROPELLANT FLOW CAPABILITY/HELIUM INGESTION.  (B) NONE.
.  (C) LOSS OF MISSION DUE TO LOSS OF PROPELLANT.  (D) NONE UNLESS FAILURE
   OCCURS WHEN MODULE REQUIRED FOR ET SEPARATION.
.CORRECTING ACTION:
.  NONE AVAILABLE - CLOSE DOWN FRCS AND ABORT MISSION.
.REMARKS/HAZARDS:
.  COMPLETE LOSS OF FRCS USAGE THEREFORE ALL ATTITUDE CONTROL MUST BE
   ACCOMPLISHED BY ARCS.
```

SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL
.ASSEMBLY :PROPELLANT FEED
.P/N RI :MC282-0061-0001/0002
.P/N VENDOR:855C332000-009/010
.QUANTITY :2
. :ONE REQ'D
. :PER PROPELLANT

FMEA NO 03-2F -111110-3 REV:11/10/76
ABORT: CRIT. FUNC: 1
CRIT. HDW: 1
MISSIONS: HF VF X FF OF SM
PHASE(S): PL LO X OO X DO X LS

REDUNDANCY SCREEN: A-N/A B-N/A C-N/A

.PREPARED BY:
.DES R BEMIS
.REL R DIEHL

APPROVED BY:
DES
REL

APPROVED BY (NASA)
SSM
REL

APPROVED WITH CHANGES
See Section 13.0

.ITEM: TANK ASSY, PROPELLANT
. INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARRIER. (TK 103).
.FUNCTION:
. TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS. NOMINA STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).
.FAILURE MODE: RESTRICTED FLOW - (S)
. STRUCTURAL FAILURE OF PROPELLANT ACQUISITION DEVICE WHICH BLOCKS OR RETARDS RATE OF FLOW OF PROPELLANT INTO TANK OUTLET.
.CAUSE(S):
. VIBRATION, MECHANICAL SHOCK, EXCESSIVE FLOW RATES DUE TO EXCESSIVE GAS IN THRUSTER MANIFOLD. (SEE FAILURE MODE NO. 4 ON NEXT PAGE).
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF FULL PROPELLANT FLOW CAPABILITY/HELIUM INGESTION. (B) NONE. (C) LOSS OF MISSION DUE TO LOSS OF PROPELLANT. (D) NONE UNLESS FAILURE OCCURS WHEN MODULE REQUIRED FOR ET SEPARATION.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) 1.5 DESIGN SAFETY FACTOR. DEVELOPMENT TESTS VERIFY WELD CYCLE LIFE, SCREEN REPAIR METHOD, SCREEN CYCLE LIFE AND SCREEN FLOW. (B) PROPELLANT ACQUISITION DEVICE COMPONENTS, SUBASSEMBLIES AND TANK ASSY INTEGRITY VERIFIED BY PERFORMING BUBBLE POINT TEST. TANKS SUBJECTED TO PROPELLANT EXPOSURE, 200 EXPULSION CYCLES, 48 MINUTES PER AXIS OF 3.9 GRMS RANDOM VIBRATION AND BURST PRESSURE DURING QUAL PROGRAM. (C) TURNAROUND INSPECT INCLUDES MONITOR FLOW DURING FUNCTIONAL TESTS. AUDIT CONDUCTER 11-1-76 VERIFIED SUPPLIER INSPECTION CONTROL OF MATL IDENTIFICATION PARTS PROTECTION MFG PROCESSES, CORROSION PROTECTION PROVISIONS, NDE EXAM OF WELDS AND STORAGE ENVIRONMENTS.
(D) NONE (NEW DEVELOPMENT ITEM).

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-111110-4

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Tank Assembly and Propellant Acquisition Device FAILURE MODE Loss of Gas in Propellant Acquisition Device

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X] NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ] NO [X]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [ ] *NO [X]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ] NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ] NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ] NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ] NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X] *1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ] YES [ ] NO [X]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X] *NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [ ] *NO [X]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. "Fail Off" detection in RCS RM.

6. No redundant tanks.

7. No correcting action - abort.

8. Same as primary.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -111110-4 REV:12/15/7
.ASSEMBLY :PROPELLANT FEED ABORT: CRIT. FUNC: 2
.P/N RI :MC282-0061-0001/0002 CRIT. HAD: 2
.P/N VENDOR:855C332000C-009/010 MISSIONS: MF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL X LC X OC X DO X LS
. :ONE REQ'D NUMBER OF SUCCESS PATHS REMAINING
. :PER PROPELLANT AFTER FIRST FAILURE: 0
. NOT DETECTABLE REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.ENGINE PERFORMANCE AND C HAMBER PRESSURE.V42P1541 SECONDS
. REFERENCE DOCUMENTS:
. MJ070-0001-01E
.GROUND TURNAROUND?.....NO SD72-SH-0103-2
. VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES R BEMIS DES _____
. REL R DIEHL REL _____
.
.
.ITEM: TANK ASSY, PROPELLANT
. INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARRIER. (TK 103).
.FUNCTION:
. TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS. NOMINAL STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).
.FAILURE MODE: LOSS OF GAS RETENTION IN (S)
. PROPELLANT ACQUISITION DEVICE (PAD).
.CAUSE(S):
. VIBRATION, SHOCK, PROPELLANT CONTAMINATION (CHEMICAL OR DIRT).
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) EXCESSIVE GAS FLOW TO THRUSTERS COULD CAUSE TANK BARRIER FAILURE.
. (B) POTENTIAL DAMAGE TO THRUSTERS IF UNDETECTED. (C) ABORT DECISION. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO LT SEPARATION.
.CORRECTING ACTION:
. SHUT DOWN FRCS AND ABORT MISSION.
.REMARKS/HAZARDS:
. IF UNDETECTED, THE THRUSTERS COULD BE DAMAGED WHICH COULD CAUSE ENTRY UNCERTAINTY.

SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -111110-4 REV:11/10/
.ASSEMBLY :PROPELLANT FEED ABORT: CRIT. FUNC: 2
.P/N RI :MC282-0061-0001/0002 CRIT. HDW: 2
.P/N VENDOR:855C3320000-009/010 MISSIONS: HF VF X FF DF SM
.QUANTITY :2 PHASE(S): PL X LO X CO X DO X LS
. :ONE REQ'D
. :PER PROPELLANT
. REDUNDANCY SCREEN: A-N/A B-N/A C-Y/
.
.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES R BEMIS DES SSM
.REL R DIEHL REL REL

APPROVED WITH CHANGES
See Section 13.0

.ITEM: TANK ASSY, PROPELLANT
. INCLUDING PROPELLANT ACQUISITION DEVICE AND COMPARTMENT BARRIER. (TK 103).
.FUNCTION:
. TO STORE/SUPPLY PROPELLANT TO REACTION CONTROL ENGINE MANIFOLDS. NOMINA STORAGE PRESSURE 245 PSIG + OR -15 (1.5 SAFETY FACTOR).
.FAILURE MODE: LOSS OF GAS RETENTION IN (S)
. PROPELLANT ACQUISITION DEVICE (PAD).
.CAUSE(S):
. VIBRATION, SHOCK, PROPELLANT CONTAMINATION (CHEMICAL OR DIRT).
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) EXCESSIVE GAS FLOW TO THRUSTERS COULD CAUSE TANK BARRIER FAILURE. (B) POTENTIAL DAMAGE TO THRUSTERS IF UNDETECTED. (C) ABORT DECISION. (D) POSSIBLE LOSS OF CREW/VEHICLE IF FAILURE OCCURS PRIOR TO ET SEPARATION.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) DESIGN FACTR OF SAFETY IS 1.5 MIN. DEVELOPMENT TESTS INCLUDE WELD CYCLE LIFE (800 CYCLES), FRACTURE MECHANICS, FORGING EVALUATION, AND TUBE SWAGING. (B) PROPELLANT ACQUISITION DEVICE COMPONENTS, SUBASSEMLIES AND TANK ASSY INTEGRITY VERIFIED BY PERFORMING BUBBLE POINT TESTS. TANKS SUBJECTED TO PROPELLANT EXPOSURE, 200 EXPULSION CYCLES, 48 MINUTES PER AXIS OF 3.9 GRMS RANDOM VIBRATION AND BURST PRESSUR DURING QUAL PROGRAM. (C) TURNAROUND INSPECTION INCLUDES PERIODIC BUBBLE POINT CHECKS OF THE PAD. AUDIT CONDUCTED 11-1-76 VERIFIED SUPPLIER INSPECTION CONTROL OF MATL IDENTIFICATION PARTS PROTECTION MFG PROCESSES, CORROSION PROTECTION PROVISIONS, NDE EXAM OF WELDS AND STORAGE ENVIRONMENTS. (D) NONE (NEW DEVELOPMENT ITEM).

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-121308-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Flex Line and Fitings FAILURE MODE External Leakage

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X] NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ] NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X] *NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ] NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ] NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ] NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ] NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ] *1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ] YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:	
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X] *NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X] *NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. V42P1115C, 1116C will give class 2 alarm.

Gross leak detection applies.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL
.ASSEMBLY :THRUSTER
.P/N RI :MC271-0084
.P/N VENDOR:74713-THRU 74717
.QUANTITY :38
. :ONE FUEL AND ONE OXIDIZ.
. :PER THRUSTER
.FAILURE DETECTABLE IN FLIGHT?. YES
.MANIFOLD PRESSURE. V#?
.GROUND TURNAROUND?.....YES
.VISUAL INSPECTION

FMEA NO 03-2F -121308-1 REV:11/10/7
ABORT: CRIT. FUNC: 1
CRIT. HWD: 1
MISSIONS: NF VF X FF OF X SM
PHASE(S): PL X LO X UO X DO X LS X
NUMBER OF SUCCESS PATHS REMAINING
AFTER FIRST FAILURE: 2
REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
TIME TO EFFECT:
SECONDS TO DAYS
REFERENCE DOCUMENTS:
MJ70-0001-018
SD72-SH-0103-2
VS70-421001

PREPARED BY:
DES J. TAGGART
REL R DIEHL

APPROVED BY:
DES _____
REL _____

.ITEM: LINE ASSEM., FLEXIBLE
. AND FITTINGS.
.FUNCTION:
. TO PROVIDE COUPLING BETWEEN PROPELLANT SUBSYSTEM AND FORWARD RCS PRIMARY AND VERNIER THRUSTER.
.FAILURE MODE: EXTERNAL LEAKAGE - (S)
. RUPTURE OF LINE OR COUPLING.
.CAUSE(S):
. FATIGUE, SHOCK, VIBRATION, HANDLING.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PROPELLANTS TO EXTENT OF LEAK SIZE. (B) INCREASED GN&C CONTROL & USE OF ALTERNATE THRUSTERS. (C) POTENTIAL MISSION TERMINATION PRIOR TO PLANNED TIME. (D) NO EFFECT AFTER ASCENT UNLESS LEAK IS EXCESSIVE & RESULTS IN IGNITION WITH REACTANT (2ND ORDER FAILURE) DURING A RTLS ABORT THE LOSS OF A MANIFOLD RESULTS IN THE LOSS OF TWO DOWN FIRING THRUSTERS WHICH RESULTS IN CRIT 1. DURING ASCENT THE FAILURE CANNOT BE DETECTED AND ISOLATED WHICH RESULTS IN POSSIBLE LOSS OF VEHICLE.
.CORRECTING ACTION:
. ISOLATE THRUSTER AT MANIFOLD.
.REMARKS/HAZARDS:
. POTENTIAL HAZARD FROM FREE FUEL IN MODULE.

SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -121308-1 REV:11/10/
.ASSEMBLY :THRUSTER ABORT: CRIT. FUNC: 1
.P/N RI :MC271-0084 CRIT. HDW: 1
.P/N VENDOR:74713-THRU 74717 MISSIONS: HF VF X FF OF X SM
.QUANTITY :30 PHASE(S): PL X LO X OO X DO X LS X
. :ONE FUEL AND ONE OXIDIZ.
. :PER THRUSTER
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/

.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES J. TAGGART DES SSM
.REL R DIEHL REL REL

APPROVED WITH CHANGES
See Section 13.0

.ITEM: LINE ASSEM., FLEXIBLE
. AND FITTINGS.
.FUNCTION:
. TO PROVIDE COUPLING BETWEEN PROPELLANT SUBSYSTEM AND FORWARD RCS PRIMARY AND VERNIER THRUSTER.
.FAILURE MODE: EXTERNAL LEAKAGE - (S)
. RUPTURE OF LINE OR COUPLING.
.CAUSE(S):
. FATIGUE, SHOCK, VIBRATION, HANDLING.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF PROPELLANTS TO EXTENT OF LEAK SIZE. (B) INCREASED GN&C CONTROL & USE OF ALTERNATE THRUSTERS. (C) POTENTIAL MISSION TERMINATION PRIOR TO PLANNED TIME. (D) NO EFFECT AFTER ASCENT UNLESS LEAK IS EXCESSIVE & RESULTS IN IGNITION WITH REACTANT (2ND ORDER FAILURE) DURING A RTLS ABORT THE LOSS OF A MANIFOLD RESULTS IN THE LOSS OF TWO DOWN FIRING THRUSTERS WHICH RESULTS IN CRIT 1. DURING ASCENT THE FAILURE CANNOT BE DETECTED AND ISOLATED WHICH RESULTS IN POSSIBLE LOSS OF VEHICLE.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) DESIGN BURST PRESSURE IS UP TO 3 TIMES THE MAX OPER PRESSURE OF 700 PSIG. PROOF PRESSURE IS UP TO 1.5 TIMES THE MAX OPER PRESSURE. THE DESIGN ALLOWS SUFFICIENT MOVEMENT TO PRECLUDE EXCESSIVE STRESSES DURING INSTALLATION AND OPERATION. LINES CAN BE ISOLATED AT THE MANIFOLD IN CASE OF LEAKAGE. (B) POST INSTALLATION TEST AND OPERATIONAL CHECKOUTS WILL VERIFY SYSTEM INTEGRITY. ALL LINES SUBJECTED TO PROOF PRESSURE DURING ATP AND RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS DURING QUAL TESTING. LINES ARE ALSO TESTED DURING SYSTEM EVALUATION AT WHITE SANDS TEST FACILITY. (C) SEE FMEA/CIL 102106-1. (D) NO HISTORY OF FAILURE IN FLIGHT. (NEW DEVELOPMENT ITEM FOR MANNED FLIGHT APPLICATION.

C-2

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-121311-1

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Injector Plate FAILURE MODE Improper Mixture Ratio

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [X]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [ ] NO [X]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [ ]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [ ]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. "Fail Off" in RCS RM if sufficiently blocked.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

```
 SUBSYSTEM :FWC - REACTION CONTROL     FMEA NO 03-2F -121311-1     REV:11/14/7.
.ASSEMBLY  :THRUSTER, PRIMARY          ABORT: ABORT          CRIT. FUNC:  1R
.P/N RI    :MC467-0028                  RTLS                 CRIT. HWC:   3
.P/N VENDOR:X30868                     MISSIONS:  MF   VF X MF   OF   SM
.QUANTITY  :14                         PHASE(S):  PL   LO X GO X OO X LS
.          :ONE INJECTOR PROVIDED FO   NUMBER OF SUCCESS PATHS REMAINING
.          :R EACH PRIMARY THRUSTER    AFTER FIRST FAILURE:              2
.                                   REDUNDANCY SCREEN:  A-FAIL  B-FAIL  C-FAI
.FAILURE DETECTABLE IN FLIGHT?. NO                      TIME TO EFFECT:
.                                                       SECONDS
.                                                       REFERENCE DOCUMENTS:
.                                                       MJC70-CC01-C1A
.GROUND TURNAROUND?.............NO                      SD72-SH-0100-2
.                                                       VS70-421001
.
.
.
.              PREPARED BY:                        APPROVED BY:
.                   DES          W SEARCY              DES  _____________
.                   REL           R DIEHL              REL  _____________
.
.
.ITEM: INJECTOR, PLATE
.
.FUNCTION:
.  TO RECEIVE FUEL AND OXIDIZER FROM THRUSTER INLET VALVES AND PROVIDE
   DOUBLET MIXING AT 1.60 OX TO FUEL (WEIGHT) RATIO FOR A HYPERGOLIC
   REACTION WHICH PRODUCES 825 POUNDS OF THRUST AT 70,000 FEET.  ALSO
   CONTROL CHAMBER WALL COOLING.
.FAILURE MODE:  FAILS TO DELIVER PROPS      (F)
.  AT PROPER MIXTURE RATIO AND FAILS TO PROVIDE ADEQUATE COOLING OF THE
   COMBUSTOR WALL.
.CAUSE(S):
.  CONTAMINATION, BLOCKED ORIFICES.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
.  (A) LOSS OF ONE THRUSTER IN A GIVEN AXIS.  (B) GN&C CONTROL SWITCHING
.  REQUIRED.  (C,D) NO EFFECT.  (E) POSSIBLE LOSS OF VEHICLE IF FAILURE
   OCCURS BEFORE ET SEPARATION.  DOWN FIRING THRUSTERS REQUIRED FOR ET
   SEPARATION.
.CORRECTING ACTION:
.  SWITCH TO REDUNDANT THRUSTER IN AFFECTED AXIS. ISOLATE MANIFOLD
   CONTAINING FAILED THRUSTER.
.REMARKS/HAZARDS:
.  POSSIBLE LOCAL HOT SPOT RESULTING IN COATING DAMAGE OR COMBUSTOR BURN
   THROUGH.
```

SUBSYSTEM :FWD - REACTION CONTROL
.ASSEMBLY :THRUSTER, PRIMARY
.P/N RI :MC467-0028
.P/N VENDOR:X30888
.QUANTITY :14
. :ONE INJECTOR PROVIDED FO
. :R EACH PRIMARY THRUSTER

FMEA NO 03-2F -121311-1 REV:11/14/78
ABORT: ABORT CRIT. FUNC: 1R
RTLS CRIT. HDW: 3
MISSIONS: HF VF X FF OF SM
PHASE(S): PL LO X OO X DO X LS

REDUNDANCY SCREEN: A-FAIL B-FAIL C-FAIL

.PREPARED BY:
.DES W SEARCY
.REL R DIEHL

APPROVED BY:
DES
REL

APPROVED BY (NASA):
SSM
REL

DELETE
See Section 13.0

.ITEM: INJECTOR, PLATE

.FUNCTION:
. TO RECEIVE FUEL AND OXIDIZER FROM THRUSTER INLET VALVES AND PROVIDE DOUBLET MIXING AT 1.60 OX TO FUEL (WEIGHT) RATIO FOR A HYPERGOLIC REACTION WHICH PRODUCES 825 POUNDS OF THRUST AT 70,000 FEET. ALSO CONTROL CHAMBER WALL COOLING.

.FAILURE MODE: FAILS TO DELIVER PROPS (F)
. AT PROPER MIXTURE RATIO AND FAILS TO PROVIDE ADEQUATE COOLING OF THE COMBUSTOR WALL.

.CAUSE(S):
. CONTAMINATION, BLOCKED ORIFICES.

.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF ONE THRUSTER IN A GIVEN AXIS. (B) GN&C CONTROL SWITCHING REQUIRED. (C,D) NO EFFECT. (E) POSSIBLE LOSS OF VEHICLE IF FAILURE OCCURS BEFORE ET SEPARATION. DOWN FIRING THRUSTERS REQUIRED FOR ET SEPARATION.

.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) 75 MICRON FILTER PROVIDED UPSTREAM TO PRECLUDE CONTAMINATION FUEL HAS BEEN FILTERED TO 25 MICRONS PRIOR TO ENTERING TANK. ACOUSTIC CAVITIES PRECLUDE OCCURRENCE OF COMBUSTION INSTABILITY IN THE EVENT OF POOR DISTRIBUTION. (B) TOTAL FLOW & FLOW DISTRIBUTION CHECKED BY WATER FLOW TEST AND VERIFIED BY BURN TEST DURING THRUSTER ACCEPTANCE TESTS. (C) FIBER OPTICS USED TO VISUALLY INSPECT INJECTOR HOLES FOR EVIDENCE OF BURRS AND CONTAMINATION PRIOR TO ASSEMBLY AUDIT CONDUCTED ON 9-2-76 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MATL VERIFICATION, PARTS PROTECTION, MFG FAB AND ASSY OPERATIONS, CONTAMINATION CONTRL, CORROSION CONTROL PROVISIONS AND STORAGE ENVIRONMENTS. TURN AROUND INSPECTION TO INCLUDE USE OF OPTICS INSPECTION WHERE ACCESSABLE FOR EVIDENCE OF DAMAGE & SYSTEM FLUID SAMPLINGS FOR DETECTION OF CONTAMINATION. (D) NO FAILURES OF THIS TYPE ON APOLLO.

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Thrust Chamber FAILURE MODE Burn Through

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [X]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[X] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

FMEA change - Measurement numbers V42X1541X through V42X1556X should be listed as V42P1541A through V42P1556A.

1. RM uses thurst chamber pressure transducers to sense the low pressure in question and give a "fail off" in RCS RM.

7. The thrust chamber measurements are downlinked.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO C3-2F -121312-1 REV:11/10/7
.ASSEMBLY :THRUSTER, PRIMARY ABORT: CRIT. FUNC: 1
.P/N RI :MC467-0028 CRIT. HWD: 1
.P/N VENDOR:X30958 MISSIONS: HF VF X FF OF SM
.QUANTITY :14 PHASE(S): PL LO X OO X DO X LS
. :ONE PER THRUSTER NUMBER OF SUCCESS PATHS REMAINING
. : AFTER FIRST FAILURE: 2
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.INCIPIENT BURN-THRU DETECTORS V42X1541X THROUGH SECONDS
.V42X1556X PC TRANS DUCER IF LEAKAGE REFERENCE DOCUMENTS:
.IS GROSS (P) MJ070-0001-01B
.GROUND TURNAROUND?.....YES SD72-SH-0103-2
.VISUAL EXAMINATION VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES W SEARCY DES _____
. REL R DIEHL REL _____
.
.
.ITEM: THRUST CHAMBER
. FROM INJECTOR TO NOZZLE EXTENSION (COATED COLUMBIUM).
.FUNCTION:
. TO CONTAIN HYPERGOLIC REACTION OF PROPELLANTS AND TO EXPAND COMBUSTION PRODUCTS TO PRODUCE THRUST THROUGH NOZZLE EXTENSION TO PROVIDE IMPULSE TO VEHICLE.
.FAILURE MODE: OVERHEAT/BURNTHROUGH (S)
. DUE TO INADEQUATE COOLING.
.CAUSE(S):
. BLOCKED (CONTAMINATED) COOLANT (FUEL) INJECTOR HOLES, POOR BOUNDARY FLOW CONDITIONS COMBUSTION INSTABILITY, SEPARATION OR FRACTURE OF PROTECTIVE DISILICIDE COATING.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF A PRIMARY THRUSTER IN A GIVEN AXIS. (B) INCREASED GNCC
. CONTROL AUTHORITY REQUIRED. (C) POTENTIAL LOSS OF MISSION ABORT DECISION. (D) POTENTIAL LOSS OF VEHICLE. CRITICAL DAMAGE COULD OCCUR BEFORE FAILURE IS DETECTED.
.CORRECTING ACTION:
. ISOLATE THRUSTER AND UTILIZE REDUNDANT THRUSTER IN AFFECTED AXIS. (AUTOMATIC FUNCTION).
.REMARKS/HAZARDS:
. POTENTIAL HAZARD FROM ESCAPING HOT GASES IN MODULE AND POTENTIAL PROPAGATION OF FAILURE IF NOT ISOLATED IN A TIMELY MANNER.

SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -121312-1 REV:11/10/78
.ASSEMBLY :THRUSTER, PRIMARY ABORT: CRIT. FUNC: 1
.P/N RI :MC467-0023 CRIT. HDW: 1
.P/N VENDOR:X30958 MISSIONS: HF VF X FF OF SM
.QUANTITY :14 PHASE(S): PL LO X OO X OO X LS
. :ONE PER THRUSTER
. :

REDUNDANCY SCREEN: A-N/A B-N/A C-N/A

.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES W SEARCY DES SSM
.REL R DIEHL REL REL

APPROVED WITH CHANGES
See Section 13.0

.ITEM: THRUST CHAMBER
. FROM INJECTOR TO NOZZLE EXTENSION (COATED COLUMBIUM).
.FUNCTION:
. TO CONTAIN HYPERGOLIC REACTION OF PROPELLANTS AND TO EXPAND COMBUSTION PRODUCTS TO PRODUCE THRUST THROUGH NOZZLE EXTENSION TO PROVIDE IMPULSE TO VEHICLE.
.FAILURE MODE: OVERHEAT/BURNTHROUGH (S)
. DUE TO INADEQUATE COOLING.
.CAUSE(S):
. BLOCKED (CONTAMINATED) COOLANT (FUEL) INJECTOR HOLES, POOR BOUNDARY FLOW CONDITIONS COMBUSTION INSTABILITY, SEPARATION OR FRACTURE OF PROTECTIVE DISILICIDE COATING.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF A PRIMARY THRUSTER IN A GIVEN AXIS. (B) INCREASED GN&C CONTROL AUTHORITY REQUIRED. (C) POTENTIAL LOSS OF MISSION ABORT DECISION. (D) POTENTIAL LOSS OF VEHICLE. CRITICAL DAMAGE COULD OCCUR BEFORE FAILURE IS DETECTED.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. INTERMETALIC DIFFUSSION LAYER FORMS AN INTEGRAL BOND BETWEEN THE DISILICIDE COATING AND THE PARENT COLUMBIUM MATERIAL AND TENDS TO RESIST SHOCK LOADING. 75 MICRON FILTER IN VALVE INLET UPSTREAM OF INJECTOR HOLES WILL PRECLUDE ENTRY OF CONTAMINANTS. ACOSTIC CAVITIES DAMPEN THE FREQUENCIES THAT EXCITE INSTABILITY. (B) SIMULATED THRUSTERS AND THRUSTER NO. 5 VIBRATION TESTS HAVE DEMONSTRATED THE ABILITY OF THE DISILICIDE COATING TO WITHSTAND 2.0 G SQUARED PER HERTZ RANDOM VIBRATION STRESSES. THRUSTER IS SUBJECTED TO RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS DURING THE QUAL. PROGRAM. (C) COATING THICKNESS AND QUALITY WILL BE CONTROLLED BY SUPPLIER INSPECTION PROCEDURE MPS 525 WHICH REQUIRES CERTIFICATION THAT COATING PROCESS CONFORMS TO THE PROCESS SPEC. VISUAL INSPECTION, VERIFICATION OF COATING THICKNESS AND A SMOKE TEST THAT VERIFIES COAT INTEGRITY. TURNAROUND INSPECTION TO INCLUDE VISUAL INSPECTION FOR EVIDENCE OF BURN THRU. (D) NO FLIGHT FAILURE HISTORY. (2) DEVELOPMENT FAILURES HAVE OCCURRED ON SHUTTLE PROGRAM. ONE FAILURE DUE TO DOUBLET DESIGN WHICH HAS BEEN CHANGED AND ONE FAILURE DUE TO THIN COAT OF DISILICIDE COATING. THIN COAT STILL WITHSTOOD MORE FIRING TIME THAN IS NORMALLY SEEN BY THE THRUSTER IN NORMAL 100 MISSION LIFE.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-121313-1

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Nozzle Extension FAILURE MODE Burn-Thru

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [ ]	NO [X]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [ ]	NO [X]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [X]	NO [ ]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [ ] 2 [X]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

3a. Instrumentation is available for software redesign.

SUBSYSTEM :FWD - REACTION CONTROL
.ASSEMBLY :THRUSTER,PRIMARY
.P/N RI :MC467-0028
.P/N VENDOR:X30872
.QUANTITY :14
. :ONE PER THRUSTER
. :
.
.FAILURE DETECTABLE IN FLIGHT?. NO
.
.
.
.GROUND TURNAROUND?.....YES
.VISUAL INSPECTION

FMEA NO 03-2F -121313-1 REV:12/18/7
ABORT: ABORT, CRIT. FUNC: 1
RTLS CRIT. HWD: 1
MISSIONS: NF VF X FF OF SM
PHASE(S): PL LO X OO X DO X LS
NUMBER OF SUCCESS PATHS REMAINING
AFTER FIRST FAILURE: 2
REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
TIME TO EFFECT:
IMMEDIATE
REFERENCE DOCUMENTS:
MJ070-0001-01E
SD72-SH-0103-2
VS70-42,001

. PREPARED BY:
. DES W SEARCY
. REL R DIEHL
.
.
. APPROVED BY:
. DES _____
. REL _____

.ITEM: NOZZLE EXTENSION,
. COATED COLUMBIUM (WITH INSULATION BLANKET).
.FUNCTION:
. TO PROVIDE FOR EXPANSION OF COMBUSTION GASES TO M>1 SUCH THAT THE REQUIRED THRUST IS PRODUCED.
.FAILURE MODE: STRUCTURAL FAILURE, (S)
. BURN-THRU.
.CAUSE(S):
. HIGH TEMPERATURE IN LOCAL SPOT DUE TO FILM COOLING FAILURE(CONTAMINATED INJECTOR COOLANT HOLES) VIBRATION, SHOCK, WELD OR MATERIAL DEFECT.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF A THRUSTER IN A GIVEN AXIS. (B) INCREASED GN&C CONTROL
. AUTHORITY REQUIRED. (C) NO EFFECT. (D) NO EFFECT UNLESS FAILURE PROPAGATES-CRIT1 FOR RTLS ABORT IF THRUSTER IS ISOLATED AT MANIFOLD LEVEL
.CORRECTING ACTION:
. ISOLATE THRUSTER AT INLET VALVE OR MANIFOLD AND UTILIZE ALTERNATE IN AFFECTED AXIS..
.REMARKS/HAZARDS:
. POTENTIAL FOR FAILURE PROPOGATION TO ADJACENT THRUSTERS IF INSULATION BLANKET DOES NOT PRECLUDE GAS/LIQUID ESCAPING. REFERENCE HAZARD 1YXX-0302-01.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -121313-1 REV:11/14/
.ASSEMBLY :THRUSTER,PRIMARY ABORT: ABORT, CRIT. FUNC: 1
.P/N RI :MC467-0028 RTLS CRIT. HDW: 1
.P/N VENDOR:X30872 MISSIONS: HF VF X FF OF SM
.QUANTITY :14 PHASE(S): PL LO X GO X DO X LS
. :ONE PER THRUSTER
. :
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/
.
.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES W SEARCY DES SSM
.REL R DIEHL REL REL
.
.
APPROVED WITH CHANGES
See Section 13.0

.ITEM: NOZZLE EXTENSION,
. COATED COLUMBIUM (WITH INSULATION BLANKET).
.FUNCTION:
. TO PROVIDE FOR EXPANSION OF COMBUSTION GASES TO M>1 SUCH THAT THE REQUIRED THRUST IS PRODUCED.
.FAILURE MODE: STRUCTURAL FAILURE, (S)
. BURN-THRU.
.CAUSE(S):
. HIGH TEMPERATURE IN LOCAL SPOT DUE TO FILM COOLING FAILURE(CONTAMINATED INJECTOR COOLANT HOLES) VIBRATION, SHOCK, WELD OR MATERIAL DEFECT.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF A THRUSTER IN A GIVEN AXIS. (B) INCREASED GN&C CONTROL AUTHORITY REQUIRED. (C) NO EFFECT. (D) NO EFFECT UNLESS FAILURE PROPAGATES-CRIT1 FOR RTLS ABORT IF THRUSTER IS ISOLATED AT MANIFOLD LEVEL
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY
. (A) INTERMETALLIC DIFFUSION LAYER FORMS INTEGRAL BOND TO RESIST SHOCK. COATING PROCESS CONTROLLED. INJECTOR DESIGN INCORPORATES ACOUSTIC CAVITIES WHICH REDUCED POSSIBILITY OF INSTABILITY. DUCTILE PROPERTIES OF C-103 COLUMBIUM PRECLUDES FRAGMENTATION OR CATASTROPHIC MODE OF FAILURE. (B) DEV VIBRATION TESTS DEMONSTRATE ABILITY OF DISILICIDE COATING TO WITHSTAND 2.0 G SQUARED/HZ RANDOM VIBRATION. TEMP TESTS DEMONSTRATE EXCELLENT DUCTIBLE/BRITTLE QUALIFIES FOR COATED C-103 COLUMBIUM. (C) TURNAROUND INSPECTION TO INCLUDE VISUAL INSPECTION FOR EVIDENCE OF BURN THROUGH & WHERE ACCESSABLE, USE OF FIBER-OPTICS NDE TO INSPECT FOR SURFACE FLAWS. SUPPLIER INSPECTION INCLUDES FLOURESCENT PENETRATE INSPECTION PRIOR TO COATING TO DETECT SURFACE DEFECTS AND X-RAY INSPECTION IS REQUIRED FOR DETECTION OF INTERNAL DEFECTS. AUDIT CONDUCTED 9-2-76 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MAT'L, IDENTIFICATION OF PARTS, MFG PROCESSES, CORROSION PROTECTION, CONTAMINATION CONTROL AND ENVIRONMENTS. (D) 4 OCCURANCES OF BELL FAILURES CAUSED BY BRITTLE HETROGENEOUS GRAIN STRUCTURE DUE TO VIBRATION FATIGUE ON APOLLO LM/SM RCS ENGINES.

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Vernier Thruster FAILURE MODE Loss of Output

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [X]	NO [ ]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [ ]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [ ]	*1 [X] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [X]	*NO [ ]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. [ ] NO H/S ISSUES	3. [ ] NO SOFTWARE DETECTION	5. [ ] ACCEPTANCE RATIONALE BELOW
2. [X] HARDWARE ACCEPTS RISK	4. [ ] DETECTION DURING CHECKOUT	6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. RM uses thrust chamber pressure transducers to sense the low pressure in question and give a "fail off" in RCS RM.

3. The GN&C RM program will automatically deselect a failed jet under certain conditions (provided it is not inhibited). See FSSR "10" paragraph 4.1.7.1.6.3 for the conditions.

6. This failure can be tolerated since it is criticality 2.

7. The thrust chamber pressures can be downlinked.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -131310-1 REV:11/14/7
.ASSEMBLY :THRUSTER ASSY ABORT: CRIT. FUNC: 2
.P/N RI :MC467-0029 CRIT. HWD: 2
.P/N VENDOR: MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO OO X OO LS
. :ONE REQ'D PER SIDE NUMBER OF SUCCESS PATHS REMAINING
. :(DOWN FIRING) AFTER FIRST FAILURE: C
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.THRUSTER CHAMBER PRESS V42P-1555A, 1556A IMMEDIATE
. REFERENCE DOCUMENTS:
. MJC70-0001-01B
.GROUND TURNAROUND?.....YES SD72-SH-0103-2
.POSITION INDICATION VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES J TAGGART DES _____
. REL R DIEHL REL _____
.
.
.ITEM: THRUSTER, VERNIER
. (EN 157/158).
.FUNCTION:
. TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUSTER FIRES IN +Z DIRECTION FOR + PITCH AND -Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR, THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP XSDUCERS.
.FAILURE MODE: LOSS OF OUTPUT (F)
. INLET VALVES/BLOCKED INJECTOR/STAND-OFF'S.
.CAUSE(S):
. CONTAMINATION, PIECE PART STRUCTURAL FAILURE, IMPROPER SOLENOID ACTUATION, VIBRATION
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF VERNIER FUNCTION. (B) NO EFFECT. (C) POTENTIAL EARLY
. MISSION TERMINATION. LOSS OF TIGHT DEADBAND ATTITUDE CONTROL. (D) NO EFFECT.
.CORRECTING ACTION:
. UTILIZE LARGE THRUSTERS FOR ATTITUDE CONTROL IN AFFECTED AXIS (INCREASED PROPELLANT QUANTITY DEPLETION)
.REMARKS/HAZARDS:
. POTENTIAL HAZARD IF FAILURE OCCURS DURING CRITICAL MANEUVERS - TIME CRITICAL. NO REDUNDANCY IS PROVIDED FOR THIS COMPONENT.

SHUTTLE CRITICAL ITEMS LIST - OPBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -131310-1 REV:11/14/78
.ASSEMBLY :THRUSTER ASSY ABORT: CRIT. FUNC: 2
.P/N RI :MC467-0029 CRIT. HDW: 2
.P/N VENDOR: MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO CO X DO LS
. :ONE REQ'D PER SIDE
. :(DOWN FIRING)
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.
.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES J TAGGART DES SSM
.REL R DIEHL REL REL
.
.
.ITEM: THRUSTER, VERNIER
. (EN 157/158).
.FUNCTION:
. TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUSTER FIRES IN +Z DIRECTION FOR + PITCH AND -Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR, THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP XSDUCERS.
.FAILURE MODE: LOSS OF OUTPUT (F)
. INLET VALVES/BLOCKED INJECTOR/STAND-OFF'S.
.CAUSE(S):
. CONTAMINATION, PIECE PART STRUCTURAL FAILURE, IMPROPER SOLENOID ACTUATION, VIBRATION
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF VERNIER FUNCTION. (B) NO EFFECT. (C) POTENTIAL EARLY MISSION TERMINATION. LOSS OF TIGHT DEADBAND ATTITUDE CONTROL. (D) NO EFFECT.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) VALVE INCORPORATES A 25 MICRON FILTER TO PRECLUDE CONTAMINATION. VALVE HAS BEEN DESIGNED TO PRECLUDE SELF GENERATED CONTAMINATES. SPECIAL EMPHASIS PLACED ON SOLENOID AND WIRING TO PRECLUDE SHORTS. (B) PRE/POST FLIGHT CHECKOUT AND VALVE SIGNATURE TESTS WHEN MODULE REMOVED. VALVE SUBJECTED TO RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS DURING QUAL PROGRAM. LENGTH OF TIME FOR VIBRATION TO EQUAL 100 MISSION LIFE EXPECTANCY. (C) AUDIT CONDUCTED 9-2-76 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MAT'L, IDENTIFICATION OF PARTS, MFG PROCESSES, CORROSION PROTECTION, CONTAMINATION CONTROL, AND ELECTRICAL TERMINATIONS. TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TEST DURING PRESSURIZATION CYCLE FOR EVIDENCE OF ERRATIC OPERATION. (D) NO FAILURE HISTORY APPLICABLE TO THIS FAILURE MODE.

SUBSYSTEM Fwd Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Vernier Thruster FAILURE MODE Erratic Operation

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES ☐	NO ☒
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES ☐	NO ☐
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES ☒	*NO ☐
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES ☒	NO ☐
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES ☐	NO ☐
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES ☐	NO ☒
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES ☐	NO ☒
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 ☐	*1 ☒ 2 ☐
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A ☐	YES ☒ NO ☐
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES ☒	*NO ☐
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES ☒	*NO ☐

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY

1. ☐ NO H/S ISSUES
2. ☒ HARDWARE ACCEPTS RISK
3. ☐ NO SOFTWARE DETECTION
4. ☐ DETECTION DURING CHECKOUT
5. ☐ ACCEPTANCE RATIONALE BELOW
6. ☐ RECOMMENDED CHANGES BELOW

No In-Flight Detectability
☒ FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. May not be detected unless 3 consecutive low pressures.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -131310-3 REV:11/10/7
.ASSEMBLY :THRUSTER ASSY ABORT: CRIT. FUNC: 2
.P/N RI :MC467-0029 CRIT. FWD: 2
.P/N VENDOR: MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO OO X DO LS
. :ONE REQ'D PER SIDE NUMBER OF SUCCESS PATHS REMAINING
. :(DOWN FIRING) AFTER FIRST FAILURE: 0
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
.THRUSTER CHAMBER PRESS. INDICATION V42P-1555A IMMEDIATE
.1556A REFERENCE DOCUMENTS:
. MJ070-0001-C1B
.GROUND TURNAROUND?.....NO SD72-SH-0103-2
. VS70-421C01
.
.
.
.
. PREPARED BY: APPROVED BY:
. DES J TAGGART DES _____
. REL R DIEHL REL _____
.
.
.ITEM: THRUSTER, VERNIER
. (EN 157/158).
.FUNCTION:
. TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUSTER FIRES IN +Z DIRECTION FOR + PITCH AND -Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR, THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP XSDUCERS.
.FAILURE MODE: ERRATIC OPERATION (F)
. LOW/HIGH THRUST OR INTERMITTENT OPERATION
.CAUSE(S):
. CONTAMINATION, IMPROPER SOLENOID ACTUATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF VERNIER CONTROL B) INTERFACE SWITCHING OF POWER AND GN&C CONTROL TO LARGE THRUSTERS. (C) POSSIBLE EARLY MISSION TERMINATION BOTH VENIER THRUSTERS WOULD HAVE TO BE ISOLATED SUCH THAT TIGHT DEADBAND ATTITUDE CONTROL WOULD BE LOST. (D) NONE.
.CORRECTING ACTION:
. SHUT DOWN/ISOLATE FAILED THRUSTER AND UTILIZE LARGE THRUSTER IN AFFECTED AXIS
.REMARKS/HAZARDS:
. POTENTIAL HAZARD FROM COLLISION. NO REDUNDANCY IS PROVIDED FOR THIS COMPONENT.

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -131310-3 REV:11/10/
.ASSEMBLY :THRUSTER ASSY ABORT: CRIT. FUNC: 2
.P/N RI :MC467-0029 CRIT. HDW: 2
.P/N VENDOR: MISSIONS: HF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO OO X OO LS
. :ONE REQ'D PER SIDE
. :(DOWN FIRING)
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/
.
.PREPARED BY: APPROVED BY: APPROVED BY (NASA):
.DES J TAGGART DES SSM
.REL R DIEHL REL REL

.ITEM: THRUSTER, VERNIER
. (EN 157/158).
.FUNCTION:
. TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUSTER FIRES IN +Z DIRECTION FOR + PITCH AND -Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR, THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP XSDUCERS.
.FAILURE MODE: ERRATIC OPERATION (F)
. LOW/HIGH THRUST OR INTERMITTENT OPERATION
.CAUSE(S):
. CONTAMINATION. IMPROPER SOLENOID ACTUATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF VERNIER CONTROL B) INTERFACE SWITCHING OF POWER AND GN&C CONTROL TO LARGE THRUSTERS. (C) POSSIBLE EARLY MISSION TERMINATION BOTH VENIER THRUSTERS WOULD HAVE TO BE ISOLATED SUCH THAT TIGHT DEADBAND ATTITUDE CONTROL WOULD BE LOST. (D) NONE.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) VALVE INCORPORATES A 75 MICRON FILTER TO PRECLUDE CONTAMINATION. VALVE HAS BEEN DESIGNED TO PRECLUDE SELF GENERATED CONTAMINATES. SPECIAL EMPHASIS PLACED ON SOLENOID AND WIRING TO PRECLUDE SHORTS. (B) PRE/POST FLIGHT CHECKOUT AND VALVE SIGNATURES TESTS WHEN MODULE REMOVED. VALVE SUBJECTED TO RANDOM VIBRATION AT ANTICIPATED MISSION LEVELS DURING QUAL PROGRAM. LENGTH OF TIME FOR VIBRATION TO EQUAL 100 MISSION LIFE EXPECTANCY. (C) AUDIT CONDUCTED 9-2-75 VERIFIED THAT SUPPLIER INSPECTION CONTROLS RAW MAT'L, IDENTIFICATION OF PARTS, MFG PROCESSES, CORROSION PROTECTION, CONTAMINATION CONTROL, AND ELECTRICAL TERMINATIONS. TURNAROUND INSPECTION INCLUDES MONITORING FUNCTIONAL TEST DURING PRESSURIZATION CYCLE FOR EVIDENCE OF ERRATIC OPERATION. (D) NO FAILURE HISTORY CONCERNING THIS FAILURE MODE.

HARDWARE/SOFTWARE ANALYSIS CHECKLIST 03-2F-131310-4

SUBSYSTEM Fwd. Reaction Control FMEA NUMBER SD75-SH-0016A

ITEM Vernier Thruster FAILURE MODE Burn-Thru

1.	DOES THE FLIGHT SOFTWARE DETECT THIS FAILURE MODE (i.e., AUTOMATICALLY ANNUNCIATE OR TAKE ACTION IN RESPONSE)?	YES [X]	NO [ ]
1a.	IF NOT, DOES THE HARDWARE PROVIDE INFORMATION THAT THE FLIGHT SOFTWARE COULD USE TO DETECT THE FAILURE?	*YES [ ]	NO [ ]
2.	ARE THE ANSWERS TO QUESTIONS 1 AND 1a CONSISTENT WITH THE FMEA EVALUATION OF IN-FLIGHT DETECTABILITY?	YES [X]	*NO [ ]
3.	DOES THE FLIGHT SOFTWARE TAKE ACTION TO NEGATE THE EFFECTS OF THE FAILURE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	YES [X]	NO [ ]
3a.	IF NOT, DOES THE CAPABILITY EXIST FOR THE SOFTWARE TO COMPENSATE FOR THIS FAILURE MODE (EITHER BY COMMANDING HARDWARE ACTION OR IMPLEMENTING ALTERNATE PROGRAM LOGIC)?	*YES [ ]	NO [ ]
4.	AS A RESULT OF THIS FAILURE MODE, CAN THE SOFTWARE OVERSTRESS THE HARDWARE OR INDUCE ANOTHER FAILURE?	*YES [ ]	NO [X]
5.	CAN THIS FAILURE MODE, IN COMBINATION WITH SOFTWARE LOGIC, ADVERSELY AFFECT OTHER FUNCTIONS?	*YES [ ]	NO [X]
6.	HOW MANY OF THESE HARDWARE FAILURES CAN THE SHUTTLE TOLERATE (CONSIDER CREW ACTION AND HARDWARE/SOFTWARE OPERATION)? NOTE CHANGE TO FMEA CRITICALITY.	*0 [X]	*1 [ ] 2 [ ]
7.	IF CREW ACTION IS REQUIRED TO RESPOND TO THIS FAILURE MODE, ARE CUES PROVIDED TO SIGNAL THE NEED FOR INTERVENTION AND THE REQUIRED CORRECTIVE ACTION?	N/A [ ]	YES [X] NO [ ]
8.	IF THE ANSWER TO EITHER 1 OR 3 IS YES:		
	A. CAN THE BFS BE ENGAGED AFTER OCCURRENCE?	YES [X]	*NO [ ]
	B. WILL BFS TOLERATE FAILURE WITHOUT LOSS OF CREW/VEHICLE?	YES [ ]	*NO [X]

*EXPLANATION REQUIRED (SEE BELOW)

CHANGE/RETENTION RATIONALE SUMMARY:

1. [ ] NO H/S ISSUES
2. [X] HARDWARE ACCEPTS RISK
3. [ ] NO SOFTWARE DETECTION
4. [ ] DETECTION DURING CHECKOUT
5. [ ] ACCEPTANCE RATIONALE BELOW
6. [ ] RECOMMENDED CHANGES BELOW

[ ] FMEA CHANGE RECOMMENDED

EXPLANATION/COMMENTS:

1. The GN&C RM Program will automatically deselect a failed jet and issue an alert. Detectable in thrust chamber but not in nozzle.

6. This is a criticality 1 failure and cannot be tolerated.

7. The thrust chamber pressures can be downlinked.

8B. Same as primary.

SHUTTLE FAILURE MODE AND EFFECTS ANALYSIS - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL FMEA NO 03-2F -131310-4 REV:12/08/7
.ASSEMBLY :THRUSTER ASSY ABORT: CRIT. FUNC: 1
.P/N RI :MC467-0029 CRIT. HWD: 1
.P/N VENDOR: MISSIONS: MF VF X FF OF SM
.QUANTITY :2 PHASE(S): PL LO OO X DO LS
. :ONE REQ'D PER SIDE NUMBER OF SUCCESS PATHS REMAINING
. :(DOWN FIRING) AFTER FIRST FAILURE: 2
. REDUNDANCY SCREEN: A-N/A B-N/A C-N/A
.FAILURE DETECTABLE IN FLIGHT?. YES TIME TO EFFECT:
. SECONDS
.MINOR LEAKAGE OR INCIPIENT FAILURE REFERENCE DOCUMENTS:
. MJC70-0001-01B
.GROUND TURNAROUND?.....YES SD72-SH-0103-2
.VISUAL EXAMINATION VS70-421001
.
.
.
. PREPARED BY: APPROVED BY:
. DES J TAGGART DES _____
. REL R DIEHL REL _____
.
.
.ITEM: THRUSTER, VERNIER
. (EN 157/158).
.FUNCTION:
. TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUSTER FIRES IN +Z DIRECTION FOR + PITCH AND -Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR, THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP XSDUCERS.
.FAILURE MODE: OVERHEAT/BURNTHROUGH (F)
.
.CAUSE(S):
. MAX PRESSURE SPIKES, SURFACE DEFECTS IN THE PROTECTIVE DISILICIDE COATING FOR CHAMBER WALL AND VIBRATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF VERNIER THRUSTER. (B) POTENTIAL DAMAGE. (C) POTENTIAL EARLY MISSION TERMINATION. (D) POTENTIAL LOSS OF VEHICLE. CRITICAL DAMAGE COULD OCCUR BEFORE FAILURE IS DETECTED.
.CORRECTING ACTION:
. ISOLATE FAILED THRUSTER AND USE OTHER THRUSTERS.
.REMARKS/HAZARDS:
. POTENTIAL HAZARD FROM ESCAPING HOT GASES IN THE MODULE AND POTENTIAL PROPAGATION OF FAILURE IF NOT ISOLATED IN A TIMELY MANNER.

SHUTTLE CRITICAL ITEMS LIST - ORBITER 102

SUBSYSTEM :FWD - REACTION CONTROL
.ASSEMBLY :THRUSTER ASSY
.P/N RI :MC467-0029
.P/N VENDOR:
.QUANTITY :2
. :ONE REQ'D PER SIDE
. :(DOWN FIRING)

FMEA NO 03-2F -131310-4 REV:12/08/78
ABORT: CRIT. FUNC: 1
CRIT. HDW: 1
MISSIONS: HF VF X FF OF SM
PHASE(S): PL LO OO X DO LS

REDUNDANCY SCREEN: A-N/A B-N/A C-N/A

.PREPARED BY:
.DES J TAGGART
.REL R DIEHL

APPROVED BY:
DES W. W. Parker
REL C. E. Barnes 12/15/78

APPROVED BY (NASA):
SSM
REL

APPROVED WITH CHANGES
See Section 13.0

.ITEM: THRUSTER, VERNIER
. (EN 157/158).
.FUNCTION:
. TO PROVIDE THRUST FOR LOW LEVEL ACCELERATIONS ASSOCIATED WITH POINTING MANEUVERS AND THREE AXIS ATTITUDE HOLD. THRUSTER FIRES IN +Z DIRECTION FOR + PITCH AND -Z ACCELERATION. INCLUDES INLET VALVE, INJECTOR, THRUST CHAMBER, NOZZLE EXTENSION, HEATER, INSULATION, PRESS/TEMP XSDUCERS.
.FAILURE MODE: OVERHEAT/BURNTHROUGH (F)

.CAUSE(S):
. MAX PRESSURE SPIKES, SURFACE DEFECTS IN THE PROTECTIVE DISILICIDE COATING FOR CHAMBER WALL AND VIBRATION.
.EFFECT(S): ON (A)SUBSYSTEM (B)INTERFACES (C)MISSION (D)CREW/VEHICLE:
. (A) LOSS OF VERNIER THRUSTER. (B) POTENTIAL DAMAGE. (C) POTENTIAL EARLY MISSION TERMINATION. (D) POTENTIAL LOSS OF VEHICLE. CRITICAL DAMAGE COULD OCCUR BEFORE FAILURE IS DETECTED.
.DISPOSITION & RATIONALE (A)DESIGN (B)TEST (C)INSPECTION (D)FAILURE HISTORY:
. (A) INTERMETALIC DIFFUSSION LAYER FORMS AN INTEGRAL BOND BETWEEN THE DISILICIDE COATING AND THE PARENT COLUMBIUM MATERIAL (C-103) AND TENDS TO RESIST SHOCK LOADING. (B) PRIOR TESTS CONDUCTED ON THE R1-1 THRUSTER HAVE DEMONSTRATED THE ABILITY OF THE DISILICIDE COATING TO WITHSTAND IMPACT LEVELS AND THERMAL STRESSES PRODUCED BY TEMPERATURES IN EXCESS OF 2900 DEGREES F. TORCH TESTS HAVE DEMONSTRATED THE INSENSITIVITY OF THE R512A COATING TO THERMAL SHOCK. (C) AUDIT CONDUCTED 9-2-76 VERIFIED THAT THE SUPPLIER INSPECTION CONTROLS RAW MAT'L, IDENTIFICATION OF PARTS MFG. PROCESSES, CORROSION PROTECTION,CONTAMINATION CONTROL, AND FLOURESCENT PENETRANT INSPECTION PRIOR TO COATING TO DETECT SURFACE FLAWS AND X-RAY INSPECTION IS REQUIRED FOR DETECTION OF INTERNAL DEFECTS. COATING THICKNESS AND QUALITY IS CONTROLLED BY MPS 525 WHICH WILL REQUIRE CERTIFICATION THAT COATING PROCESS CONFORMS TO THE PROCESS SPECIFICATION, VISUAL INSPECTION, VERIFICATION OF COATING THICKNESS & TEST TO VERIFY COATING INTEGRITY. TURNAROUND INSPECTION TO INCLUDE VISUAL INSPECTION FOR EVIDENCE OF BURN THROUGH AND WHERE ACCESSIBLE. USE OF FIBER OPTICS NDE TO INSPECT FOR SURFACE FLAWS.
(D) NO FLIGHT FAILURE HISTORY.

Meeting Minutes

Review of JSC 14651, Hardware/Software Interaction Analysis Volume VIII, Forward Reaction Control System Part 1 of 2.

1. Meeting held at Rockwell International, Downey, 1:00PM to 2:30PM, 9/24/79.

2.

Attendees	Organization	Phone
Edward Vonusa	NASA	X-1470
Dave Latham	JSC Reliability (Boeing)	527-0323 FTS
Rudy Kubica	RI Propulsion/RCS	X-4720
Larry Gladu	RI System Engineering	X-1189
Bill Meyers	RI System Engineering	X-1726
Bob Diehl	RI Reliability	X-2098

3. The following changes were discussed and will be incorporated in the final release of Forward Reaction Control System Hardware/Software Interaction Analysis and will be reflected in next update of Fwd RCS FMEA:

03-2F-101010-1: Change "SMU" to "SM". Insert "SM Alert" before "blue light."

03-2F-101013-1: Same as 03-2F-101010-1.

03-2F-101020-3: Same as 03-2F-101010-1.

03-2F-101020-4: Same as 03-2F-101010-1.

03-2F-101030-1: Add "X" in No. Block, question 1a.

03-2F-101030-2: Add V42P1116C to Explanation 1. and 2.

03-2F-101060-1: Show class 3 alarm with blue light and class 2 alarm with red light. Add V4211116C. (Explanation 1.)

03-2F-101060-2: Add "X", No Block, question 1a.

03-2F-101060-3: Same as 03-2F-101060-1.

03-2F-101060-4: Same as 03-2F-101060-1.

03-2F-101060-5: Same as 03-2F-101060-1.

03-2F-101070-1: Under 1 & 2 Explanation, add V4211113C, 1114C. Change class 2 to 3.

03-2F-101080-1: Change FMEA to show detectability method.

03-2F-101090-1: Under 1 & 2 Explanation, change V42P1110C, 1112C to 1113C, 1114C. Change class 2 to 3. Add gross leakage detectability (see 03-2F-101080-1).

03-2F-101095-2: Change "X" from Yes Block to No Block, question1. Under Explanation, delete 1 & 2 (failure is one leg only - requires failure of both legs to actuate C & W).

03-2F-102106-1: Under 1 Explanation, add gross leakage detectability (see 03-2F-101080-1). Under 7 Explanation and FMEA change add V42P1115C. Change FMEA to show detectability.

03-2F-102108-1: Under 1 Explanation, add gross leakage detectability (see 03-2F-101080-1) Under 7 Explanation add V42P1115C.

03-2F-102120-1: Under 1 Explanation, add oxidizer measurement numbers, and add "failed off thruster will give "failed jet on C & W".

03-2F-102150-1: Same as 03-2F-102120-1 plus retain V42P1312C and delete 1313C and 1314C.

03-2F-102170-1: Under 1 Explanation, add measurements V42X1333X, 1233X. Change class 2 to 3.

03-2F-111110-1: Under 1 Explanation, add V42P1210C, 1212C, 1216C and add to to FMEA detectability. Add X in FMEA change recommended block.

03-2F-111110-2: Same as 03-2F-111110-1.

03-2F-111110-3: Under 1 Explanation, add gross leakage detectability (see 03-2F-101080-1)

03-2F-11111-4: Change X from No Block to Yes block for question 1. Under Explanation, delete 1st paragraph and 1. (White Sands Test on vernier showed complete loss chamber pressure which is detectable. Similar gas bubbles in propellant tests are planned for primary thrusters).

03-2F-121308-1: Under 1 Explanation, the class 3 alarm is doubtful. Check and verify findings with Bill Meyers RI Systems Engineering. Also add gross leakage detectability (see 03-2F-101080-1).

03-2F-121311-1: Change Failure Mode to agree with failure mode in FMEA.

03-2F-121312-1: Under 1 Explanation, add "If failure is upstream of throat it will be detected by PC; if failure is downstream of throat it will not be detected."

03-2F-121313-1: Change X from Yes Block to No Block, question 1. Delete 1. under Explanation (failure is downstream of throat and will not be detected by PC).

03-2F-131310-3: Change X from Yes Block to No Block, question 1. Add X to FMEA change recommended block. Under 1. Explanation, delete entire sentence (the pressure transducers are snubbed by an orifice and will not detect the erratic operation). Change FMEA to indicate no detectability.

Approved by:

Larry Glad, RI
System Engineering

Dave Latham
JSC Reliability (Boeing)

Edward Vonusa
NASA QARSO

NASA-JSC

Document Number: JSC 14651

Title: HARDWARE/SOFTWARE INTERACTION ANALYSIS
Volume VIII, Forward Reaction Control System, Part 1 of 2

Prepared by: NB - Reliability Division

Distributed by: NB - SR&QA Data Center

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